Spinoff 1981

An Annual Report

National Aeronautics and Space Administration

Foreword

This is the Year of the Space Shuttle, an epochal milestone in American space progress. The Shuttle's debut marks the beginning of a new era, an era of significantly broadened capability to pursue the many opportunities the space medium affords for practical benefit to the people on Earth.

Pursuit of benefits from aerospace research and development has been a NASA goal since the agency's inception 23 years ago. The quest has been notably successful.

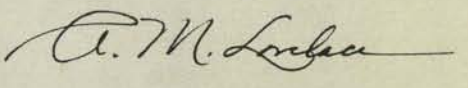
The communications and environmental satellites now in operational service trace their origins to NASA programs of earlier years. In developmental status is a space-based system for monitoring Earth, a system of sweeping potential for more effective management of our planet's far-from-limitless resources.

Among the most important space benefits, though perhaps the least understood, is the wealth of information produced by the scores of scientific spacecraft which have probed Earth's environs and the distant reaches of the solar system. Their product is knowledge, a resource for tomorrow's employment, a valuable legacy to future generations.

Additional benefits have accrued from NASA's aeronautical research effort. Many of the design features and on-board systems of today's aircraft had their genesis in NASA laboratories. The agency's work has contributed in substantial degree to safer, more efficient, more productive, more environmentally acceptable flight.

Still other dividends have been realized through secondary use of the technology generated in major programs: the economic and social values represented by the thousands of new products and processes that owe their existence to aerospace research and development.

For all these accomplishments, we have really just begun to tap the aerospace benefit potential. The impressive results of past endeavor are but prelude to the greater promise of coming years.



A. M. Lovelace

Acting Administrator
National Aeronautics and
Space Administration

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National Aeronautics and
Space Administration

Office of Space and
Terrestrial Applications
Technology Transfer Division

by James J. Haggerty

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April 1981

On the cover:

Artist Paul Salmon depicts a milestone moment in the annals of space flight, the initial launch of NASA's Space Shuttle, which heralds a new era of routine access to orbit and expanded opportunity for exploiting the promise of space.

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Introduction

In 23 years of meeting space and aeronautical research goals, NASA has developed a great storehouse of technology. Like other forms of knowledge, technology is transferable. It can be applied in ways other than that for which it was originally intended, to the benefit of the national economy. Thus, the wealth of knowledge in the NASA technology repository represents a valuable resource, a legacy of the national investment in aerospace research.

Through technology transfer, NASA seeks to promote wider use of this resource in the interest of expanded national productivity and improved quality of life. The intent is to stimulate the transfer process by making the technology more accessible to those who might put it to advantageous use.

This publication is an instrument of that intent, designed to heighten awareness of the technology available for transfer and its potential for public benefit. Its title—Spinoff—has dual meaning. In the specific sense, spinoff refers to the thousands of products and processes that have emerged from secondary use of aerospace technology. In a broader sense, spinoff is the use of aerospace technology to do Earth jobs better. Hence, in the context of this volume, spinoff embraces both indirect secondary applications and technology transfer of a direct nature. The latter is exemplified by the agency's efforts to broaden beneficial applications of satellite remote sensing technology.

Section 1 summarizes NASA's mainline programs, whose benefit-oriented objectives require development of new technology and therefore expand the bank of technology available for transfer in future years.

Section 2 contains a representative sampling of spinoff products and processes resulting from technology utilization, the secondary application of aerospace technology.

Section 3 details the mechanisms of the technology transfer process, including the means by which NASA seeks to stimulate technology utilization and facilitate broader application of satellite remote sensing technology.

Floyd I. Roberson, *Director*

Technology Transfer Division
Office of Space and
Terrestrial Applications

National Aeronautics and
Space Administration

April 1981

Contents

2 **Foreword**

5 **Introduction**

Aerospace Aims

8 Space Shuttle: Link to Orbit

14 Science and Technology for National Benefit

24 Research for Energy

32 Toward Future Flight

42 Exploring the Cosmos

Technology Twice Used

52 Prologue

Spinoffs in:

56 Industrial Productivity

64 Public Safety

74 Home and Recreation

80 Computer Processes

88 Health and Medicine

98 Energy

108 Community Service

Technology Transfer

116 Putting Technology to Work

3 2 1

Aerospace Aims

An illustrated summary of NASA's mainline programs, their missions and goals, and the many ways in which they are producing direct benefits to Earth's people

Space Shuttle: A Link to Orbit

Economy and versatility are the keynotes of the Space Transportation System, which will expand opportunities for space-derived Earth benefits

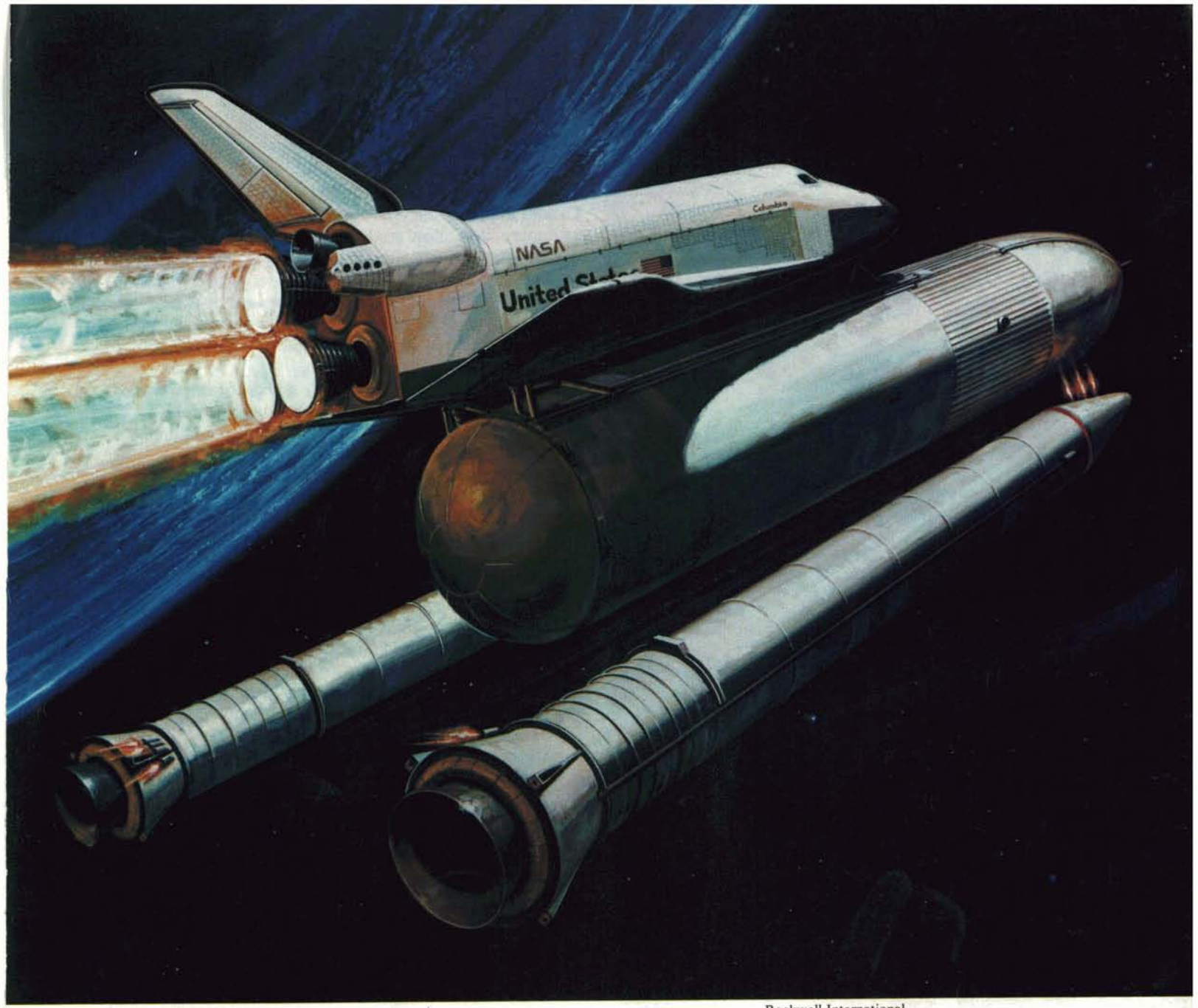
Last year, in preparation for the orbital debut of the Space Shuttle, NASA acquired a two-ship "navy." The ships will be used to recover at sea the Shuttle's two solid rocket boosters and the parachutes that lower them to the surface. Recovery and subsequent refurbishing of the rocket casings will permit reuse of the boosters for as many as 20 launches. This underlines one of the most important features of the Space Shuttle: substantial reduction in mission costs through reuse of the two principal Shuttle elements—the boost system and the manned Orbiter, which lands like an airplane at Earth bases.

An additional factor in Shuttle economy is retrieval of unmanned satellites. The Orbiter can fly to a rendezvous with a satellite, grapple it by means of a robot arm and deposit it in the Orbiter's cargo bay. There, astronauts can replace equipment modules to correct malfunctions or to update the satellite's capability by substituting more advanced equipment. When necessary, the Orbiter can return the satellite to Earth for rework, then redeliver it to space on a later flight. Thus, retrievability provides lengthy extension of a satellite's useful life and allows large-scale savings in replacement costs.

The Space Shuttle is the principal component of the Space Transportation System, which initially includes the Spacelab—a manned laboratory carried in the Orbiter's cargo bay—and three types of upper stage "space tugs" for boosting payloads to orbits beyond the Shuttle's operational altitude. Space Transportation System additions contemplated for later development include orbital power stations for large-scale electrical needs, more advanced space tugs, robot systems for in-space maintenance and construction tasks, and a heavy-lift vehicle for delivering to orbit greater payloads than the Shuttle can accommodate.

The Space Transportation System enables more efficient performance of traditional space tasks and allows accomplishment of direct benefit operations earlier considered impracticable or overcostly. For example, the availability of the system opens up an entirely new realm of space potential: erection in orbit of large structures to serve such purposes as revolutionary advances in communications, or manufacture in weightless space of certain items less efficiently produced, or not producible at all, in the presence of Earth's gravity.

The versatile Space Shuttle offers unprecedented operational flexibility. From bases on either coast, the Shuttle Orbiter can deposit satellites in any desired orbit. On many missions it will carry multiple payloads. It can serve as an orbital launch facility for sending interplanetary spacecraft into deep space trajectories. And in addition to



Rockwell International

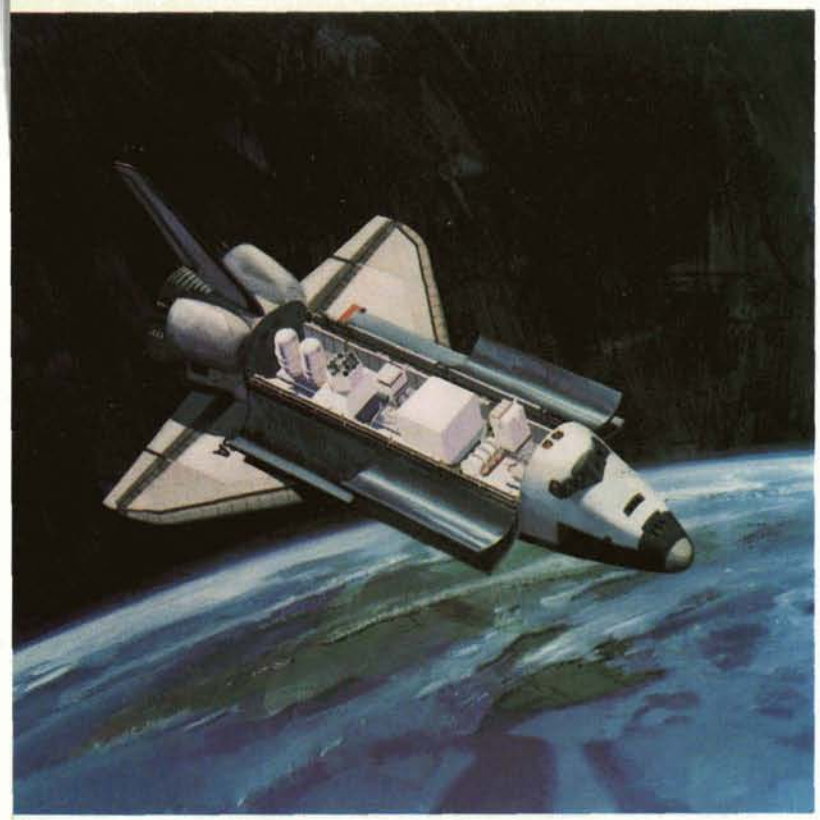
its delivery/retrieval role, the Orbiter—when fitted with the Spacelab—becomes a human-staffed space station for stays aloft as long as 30 days.

Capable of delivering payloads up to 65,000 pounds to an altitude of almost 700 miles, the Orbiter is built by Rockwell International Corporation. Rockwell is also prime contractor for integration of the overall Shuttle system. Both Orbiter and integration contracts are managed by Johnson Space Center.

The solid rocket boosters are produced by Thiokol Corporation, and Martin Marietta Corporation supplies the huge external tank which houses fuel and oxidizer for the Orbiter's three main engines; these contracts are managed by Marshall Space Flight Center. Under contract with Kennedy Space Center, United Space Boosters, Inc. handles solid rocket launch functions, including operation of the recovery ships and refurbishment of the boosters. The European Space Agency is responsible for the Spacelab component.

The initial Space Transportation System—the Shuttle—will undergo a series of trial flights before beginning operational service in the latter part of 1982. With its operational debut will come a significantly expanded capability for doing useful work in orbit, thus to pursue more vigorously the many benefits afforded by routine, economical access to space.

This artist's concept depicts a moment two minutes after Shuttle launch when the large solid rockets have completed their job of boosting the Orbiter to an altitude of 30 miles. Pushed clear by small rocket motors, the spent boosters are lowered by large parachutes to the sea, where they are picked up by recovery ships Liberty *and* Freedom *(at left). Drawing fuel from the big external tank, the Orbiter's three main engines power the spacecraft for another six minutes. Just before orbital velocity is attained, the external tank is jettisoned and not recovered. An orbital maneuvering system, fueled from tanks within the Orbiter, provides the final thrust into orbit.*

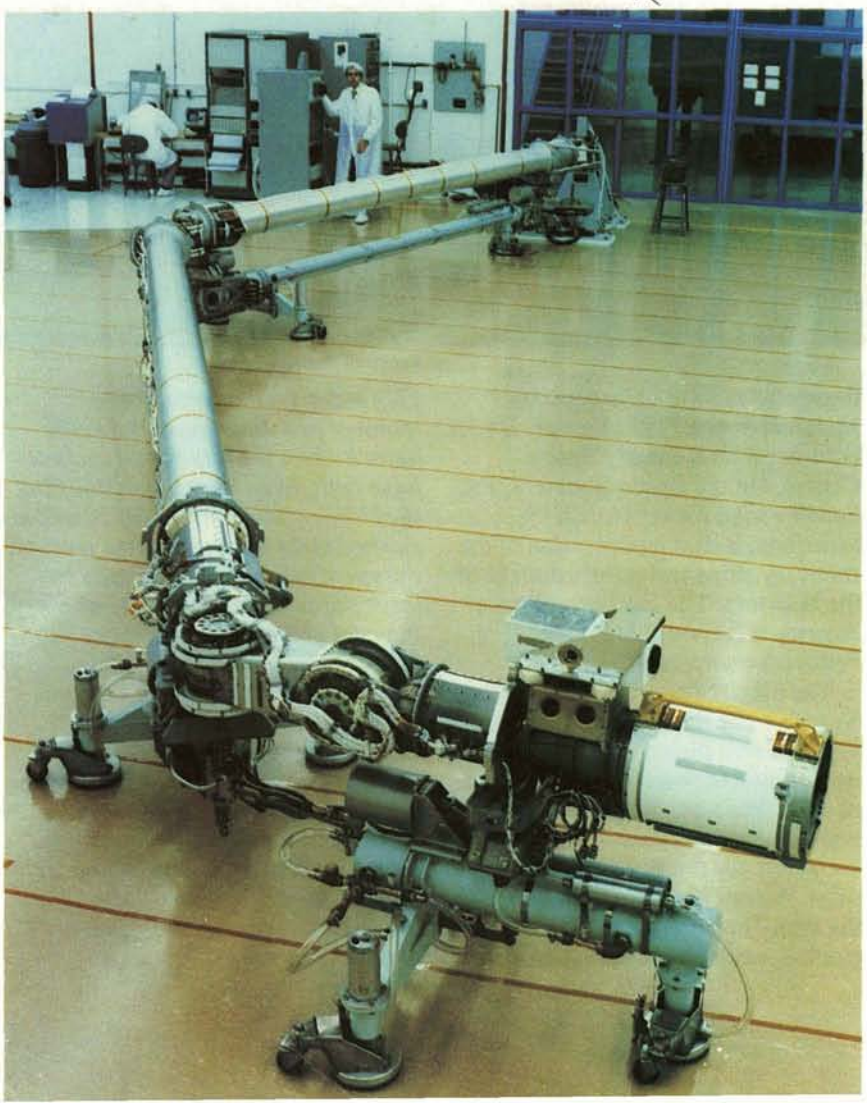


Shuttle Trials

Initial operation of the Space Shuttle involves four Orbital Flight Tests (OFT) intended to verify Shuttle systems and to allow study of the environments in which the Shuttle Orbiter (left) will be operating. To be made by the Orbiter *Columbia*, the flights will range in duration from two to seven days and will be crewed by two astronauts; on some later operational missions, duration will be extended to 30 days and crew complement increased to a maximum of seven.

On each OFT flight, the Shuttle will carry extensive instrumentation for performance evaluations of the Shuttle's many systems. Additional instrumentation is designed to provide detailed measurements of the environments associated with Space Transportation System (STS) operations and to gather information of importance to future missions.

The Shuttle will carry its first scientific payload on STS-2, the second orbital flight test. Designated OSTA-1 for its sponsor—NASA's Office of Space and Terrestrial Applications—the payload consists of seven experiments in Earth resources applications, five of them mounted on a 10-foot pallet that fits into the Orbiter's cargo bay. OSTA-1 will be the first of many pallets to be flown by the Shuttle. Use of pallets—which remain in the cargo bay throughout a mission—permits accomplishment of

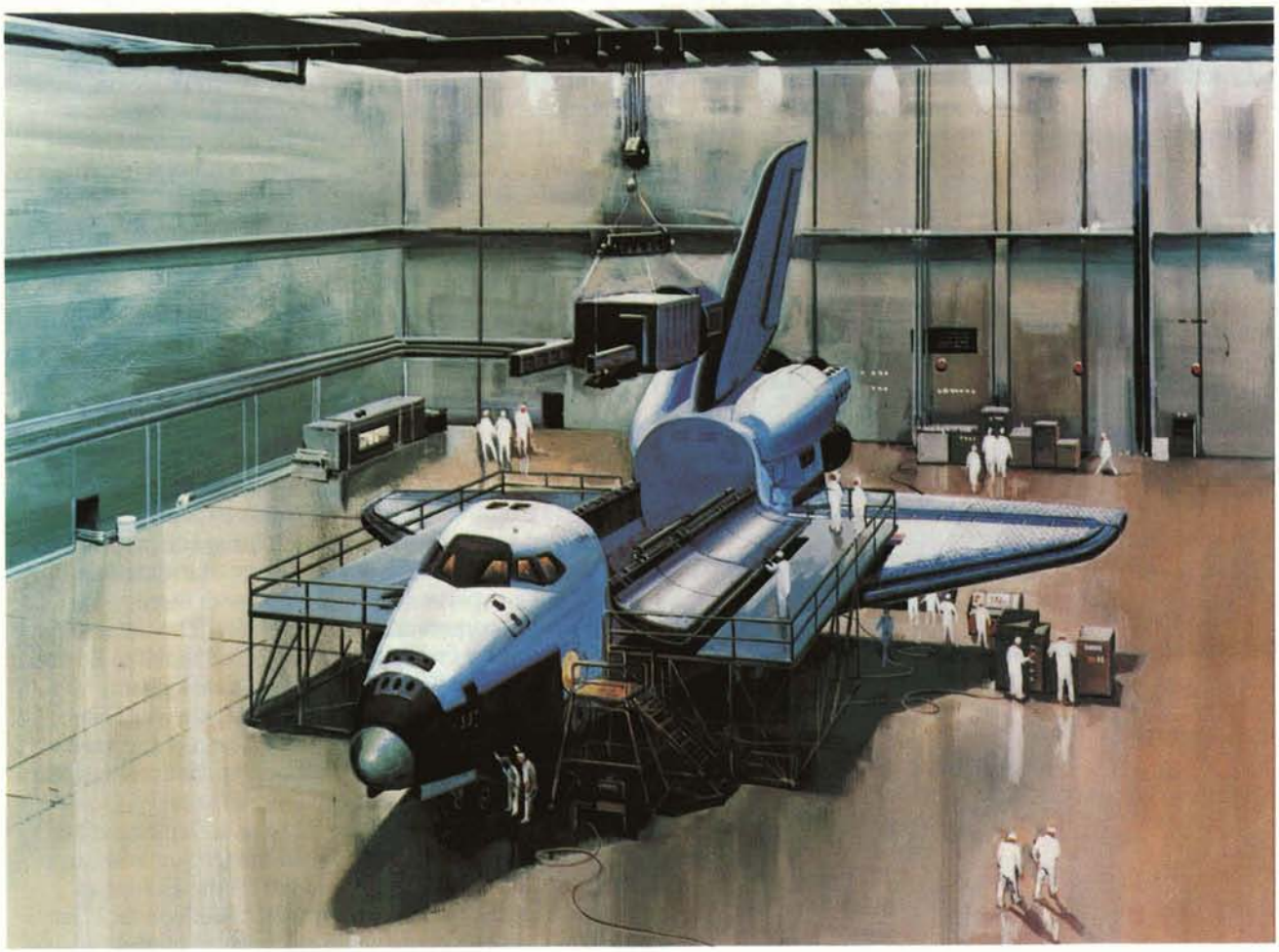


experiments and tests of advanced instrumentation without the expense of developing free-flying satellites.

The third OFT flight (STS-3) will be devoted to checkout of the Orbiter's Payload Deployment and Retrieval System, principal element of which is a 50-foot, triple-jointed robot manipulator controlled from the Orbiter's flight deck. Developed by the National Research Council of Canada and built by SPAR Aerospace Ltd., the mechanical arm will be used on future missions to lift satellites out of the cargo bay and deposit them in space; on some missions it will be employed to retrieve orbiting satellites for repair in space or return to Earth for rework. On the opposite page, the lower left photo shows the manipulator undergoing ground test, the adjacent illustration its use in orbit.

On the final test flight, the Orbiter will carry either a Department of Defense payload or OSS-1, a palletized instrument package designed by NASA's Office of Space Science (left). OSS-1 consists of seven scientific experiments in space plasma physics, solar observation, astronomy and life sciences.

The four OFT flights will also serve to evaluate the Earth-based elements of the Space Transportation System, including assembly, checkout, launch and mission control facilities; the recovery and renovation process for the solid rocket boosters; and the Orbiter Processing Facility at Kennedy Space Center (below), where the Orbiter is refurbished for its next flight.



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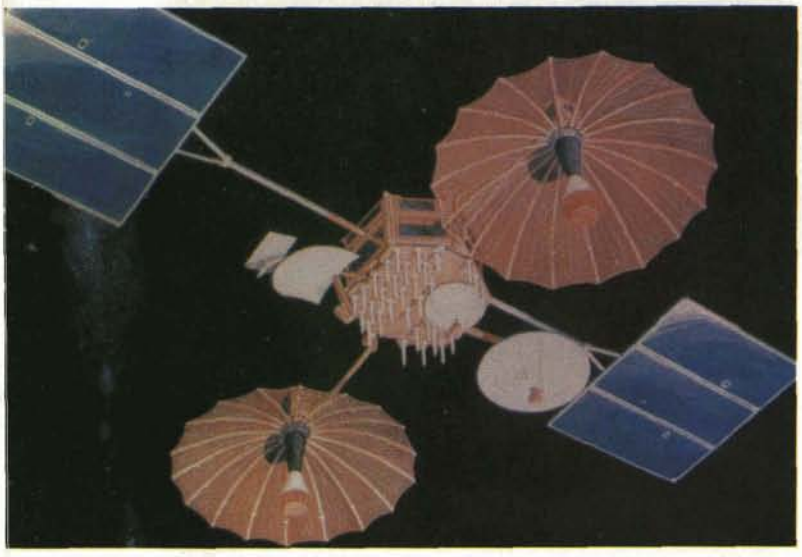


Operational Flights

Upon completion of the four Orbital Flight Tests, the Space Shuttle will begin regular operational service. A résumé of the first six tentatively planned assignments gives an idea of the type of work the Shuttle will be performing in the early years of its operation.

On these and later missions, upper stages will be used to boost payloads to high-altitude orbits, for example, interplanetary trajectories or the geostationary orbit (22,300 miles) wherein most communications satellites operate. For large payloads, the boosters will be the Inertial Upper Stage (left), built by Boeing Aerospace Company, and the Centaur, built by General Dynamics Corporation. Smaller satellites will be boosted by a Solid Spinning Upper Stage (SSUS), so called because it spins like a gyroscope to maintain stability. Built by McDonnell Douglas Corporation, the SSUS comes in two sizes for different payload classes.

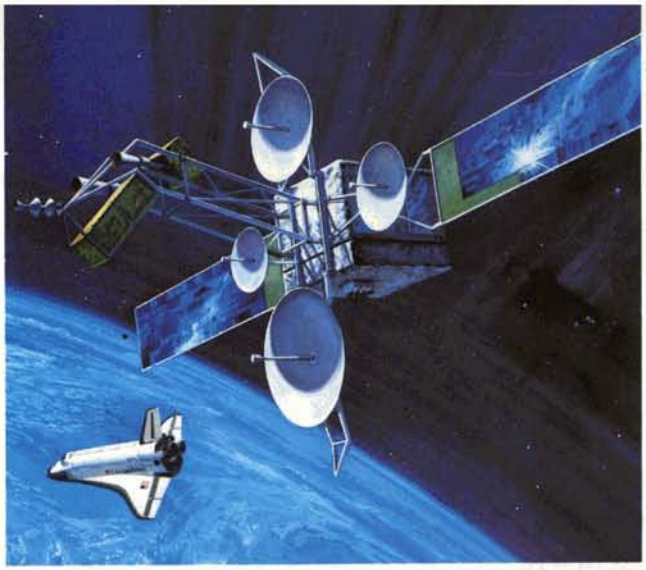
STS-5, the first operational flight, involves delivering to geostationary orbit the first of two Tracking and Data Relay Satellites (TDRS), which are essential parts of the Space Transportation System. Deposited in low orbit by the Shuttle Orbiter, the TDRS (below) will be boosted to the higher altitude by an Inertial Upper Stage. The TDRS, built by TRW Inc., will serve as a relay station for communications among Earth bases, the Orbiter and unmanned payloads in space. The two NASA satellites, along with one backup in orbit and another intended for commercial use, will be operated by Space Communications, a subsidiary of Western Union, Fairchild Industries and Continental Telephone.

On STS-6, which will mark the debut of the Orbiter *Challenger*, the Shuttle will deliver a multiple payload that includes two commercial communications satellites, Canada's Telesat E and a Satellite Business System spacecraft; they will be boosted to geostationary orbit by Solid Spinning Upper Stages. Also on board the Orbiter will be West Germany's Shuttle Pallet Satellite, a platform containing a complement of experiments; the pallet will be deployed outside the Orbiter as a further test of the Remote Manipulator System.

On STS-7, the Orbiter will deliver the second NASA Tracking and Data Relay Satellite. It will also carry in its cargo bay an Office of Aeronautics and Space Technology (OAST) pallet. OAST-1 will contain experiments in advanced solar power generation for space propulsion.

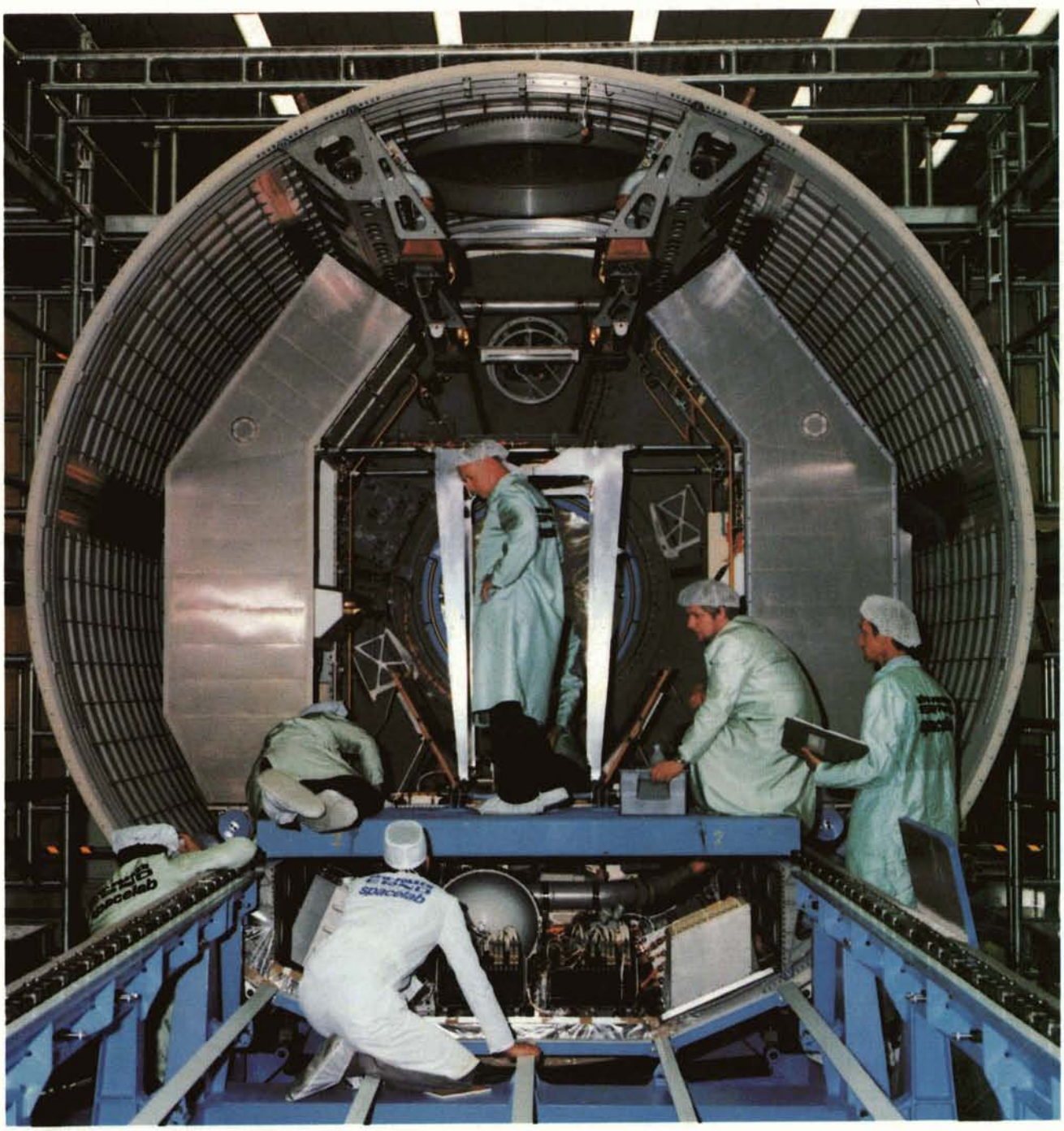
The payload for STS-8 will consist of a materials processing experiment pallet along with three commercial communications satellites. The latter include additional spacecraft of the Telesat and Satellite Business System series and one of RCA's Satcom system; two of those three will be flown. The other satellite (shown at top right) is an Intelsat V, part of the space communications network operated by the International Telecommunications Satellite Organization.

Tentatively scheduled for STS-9 is a Department of Defense payload, and on STS-10 the Orbiter will carry aloft the first Spacelab, developed by the European Space Agency. Spacelab 1 (shown under construction at right) has two elements: a pressurized module where



two scientists work in shirtsleeve environment and an experiment pallet whose instruments will be directly exposed to space in the open cargo bay. The scientists—called payload specialists—will conduct a wide range of scientific and technological investigations over a five-day span.

On later missions, in addition to payload deliveries, the Space Transportation System will be used to retrieve Earth-orbiting satellites, to launch planetary spacecraft, and to conduct experiments in erection of structures in orbit. Mission frequencies will increase as Orbiters *Discovery* and *Atlantis* join *Columbia* and *Challenger*. A long-range "traffic forecast" envisions 487 flights over the first 12 years of operations.



Science and Technology for National Benefit

NASA's applications program employs aerospace technology and scientific knowledge to serve the needs of industry and the public

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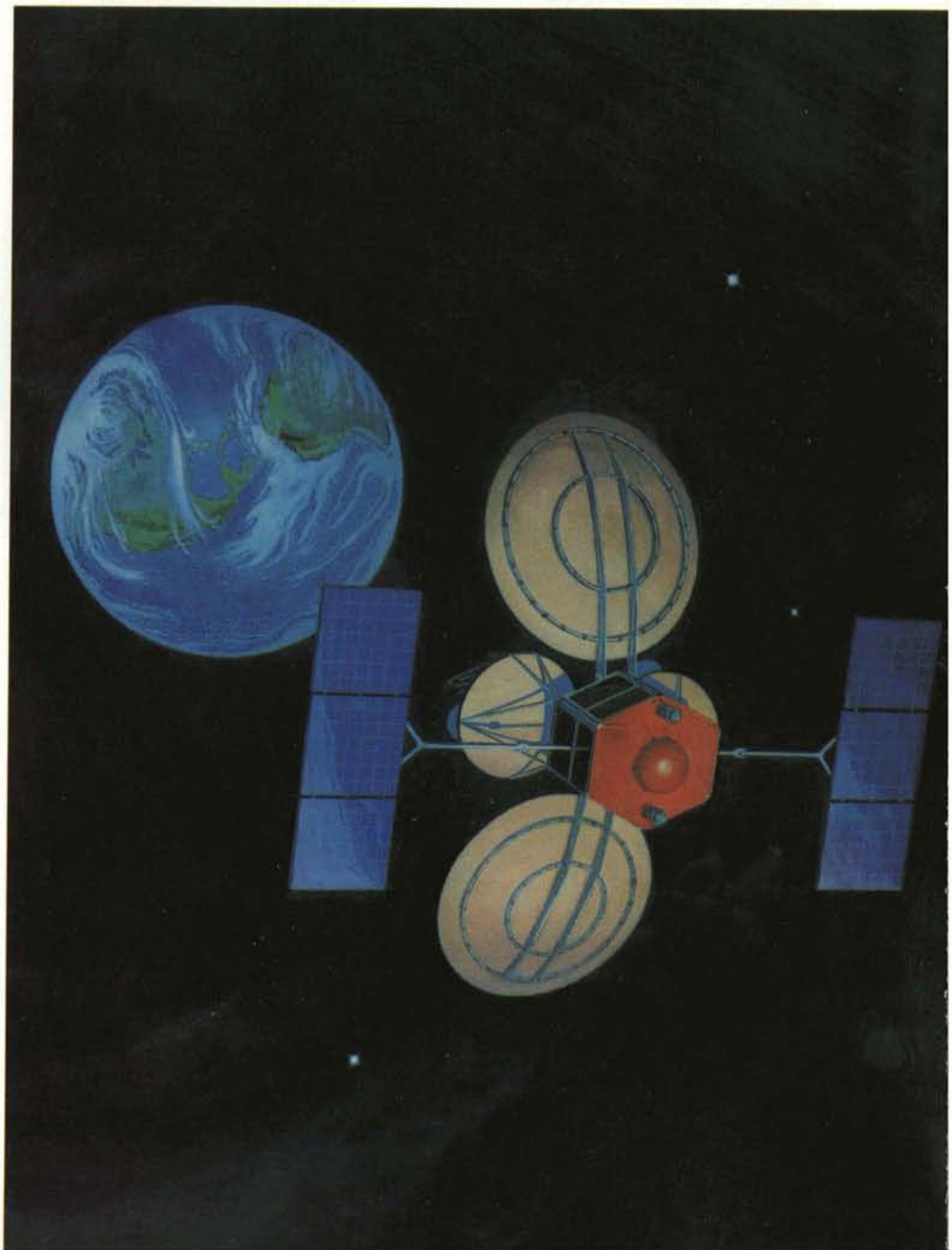
In the early 1960s, NASA pioneered research and development of communications satellites and built a technological foundation for commercial employment of spacecraft as communications relay stations. Inaugurated in 1965, commercial satellite systems have grown beyond the most optimistic expectations. Two-thirds of all overseas communications traffic is now carried by satellites, a number of domestic satellite systems are in operation, and there are specialized networks for such purposes as business and marine traffic. The result is that the segment of space used by "satcoms" is already crowded and bids to become more so. This orbital congestion is a barrier to needed expansion of satellite communications because proximity can cause one satellite's signals to interfere with another's.

New technology is the answer, but its development entails high risk beyond the resources of private sector communications carriers. Since a solution is very much in the public interest, NASA has embarked



To ease an imminent space communications logjam, NASA is developing technology for advanced "multibeam" satellites operating in a new frequency band.

on a program to ease the space communications traffic jam.

Satcoms operate in what is known as "geostationary orbit"—one in which the satellite's velocity is synchronized with Earth's rotational speed, so that the satellite remains "stationary" with respect to a point on Earth. The requisite altitude is 22,300 miles and all synchronous satellites operate at that height, positioned so that they "view" a particular geographical area. The part of space that is especially crowded is the "geostationary arc" where more than a score of satcoms relay communications to ground stations in North America.

Satcoms operate in two frequency ranges, one known as C-band and another of higher frequency called Ku-band. C-band is already saturated and Ku-band is expected to become so by the latter 1980s. Projections indicate that demand for satcom service will continue to increase on a dramatic scale. The crux of the problem is to allow major expansion without degrading communications quality, and that calls for more effective use of the radio spectrum and the limited number of geostationary satellite positions available.

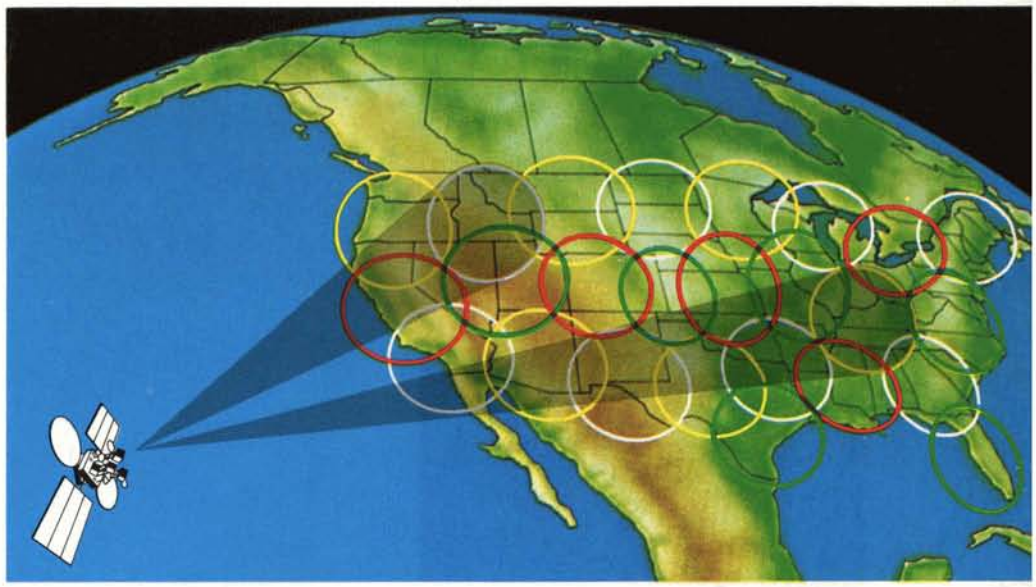
One of NASA's approaches is analogous to creating a new highway to ease vehicular traffic congestion. It calls for opening up a still higher frequency range known as Ka-band, a band not yet used because it is highly susceptible to weather-caused interference and the technology for its employment does not exist.

Another approach compares with adding new lanes to an existing Earth highway. This involves development of techniques enabling simultaneous transmission of multiple messages in the same frequency band. A related line of research contemplates advanced satellite equipment capable of generating multiple "spot" beams, each focused on a narrow Earth region, rather than the wide beams now generated. Spot beams operating in the same frequency can handle many messages without interfering with one another, but this method would need a switching system on board the satellite to interconnect the receiving stations on Earth.

Accomplishment of these improvements requires extensive technology development—new types of antennas in space and on Earth, greater power for transmissions, complex switching systems and a number of other advancements. If successfully developed, however, the combination of improvements envisioned would afford sufficient capacity to meet satellite communications demand well into the 21st century.

NASA is also developing technology in an area not yet served by commercial carriers—public service communications for such purposes as education, health care, emergency medical service, electronic postal service, fire fighting and disaster response. A related effort is aimed at linking communications satellites with mobile land terminals to serve a variety of public safety needs, for instance, improved communications between hospital physicians and ambulance paramedics en route to the hospital. Finally, looking further into the future, NASA is exploring the feasibility of large platforms in geostationary orbit providing power, antennas and other functions for a number of payloads—in effect, one satellite in one geostationary position taking the place of many satellites.

This communications technology development effort is one element of what NASA calls its applications program, which has the aim of generating public benefit through direct application of aerospace technology. For the past several years, the main focus of the program has been development and demonstration of Landsat resource monitoring satellites, which offer important benefits in a wide range of practical uses. NASA has developed several other applications spacecraft, among them advanced weather observation satellites, environment monitors and climatic research systems. A new applications area is investigation of processing materials in orbit, a step toward future manufacture of products better produced in the weightless environment or not at all producible under conditions of Earth gravity. In addition, NASA pursues non-space applications intended to solve problems or meet important civil needs through development of ground-based or aircraft-borne systems. This applications effort has already produced public benefits of substantial order and promises even greater dividends to the nation in future years.



One method of increasing satellite communications capacity is generation of multiple "spot" beams, each focused on a narrow Earth region, rather than the wide beams now generated. A switching system on board the satellite would interconnect the receiving ground regions.

Landsat

The Landsat resources survey satellite offers a means of monitoring changing conditions on Earth's surface by a process known as remote sensing, in which spaceborne sensors detect various types of radiation emitted or reflected from objects on Earth. Computer-processed at ground facilities and translated into tapes or images, Landsat data can be interpreted to differentiate among a broad variety of surface features. This information can be put to practical use in such applications as agricultural crop forecasting, rangeland and forest management, mineral and petroleum exploration, mapping, land use management, water quality evaluation and disaster assessment.

The space segment of the system consists of two General Electric-built satellites, Landsat 2 and 3. A new and advanced member of the satellite family—the Landsat D pictured—will augment the system in 1982. The experimental program, managed by Goddard Space Flight Center, has for several years provided valuable information to many users, including state and local governments plus a number of commercial firms. Its demonstrated success as a tool for more effective management of Earth's resources led to a Presidential decision to establish an operational civil land remote sensing satellite system, to be based initially on Landsat technology. The system will be operated by the National Oceanic and Atmospheric Administration of the Department of Commerce, with a goal of eventual private sector ownership and operation.

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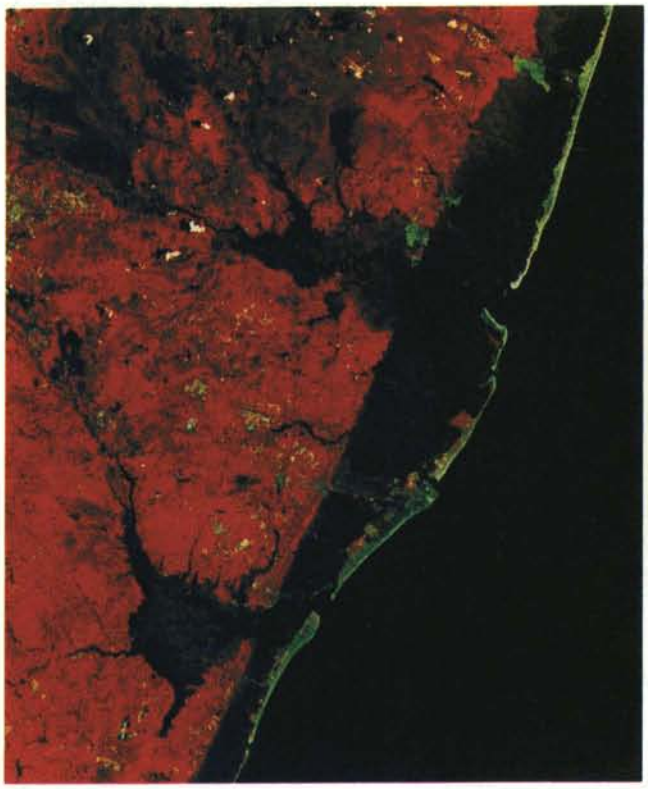

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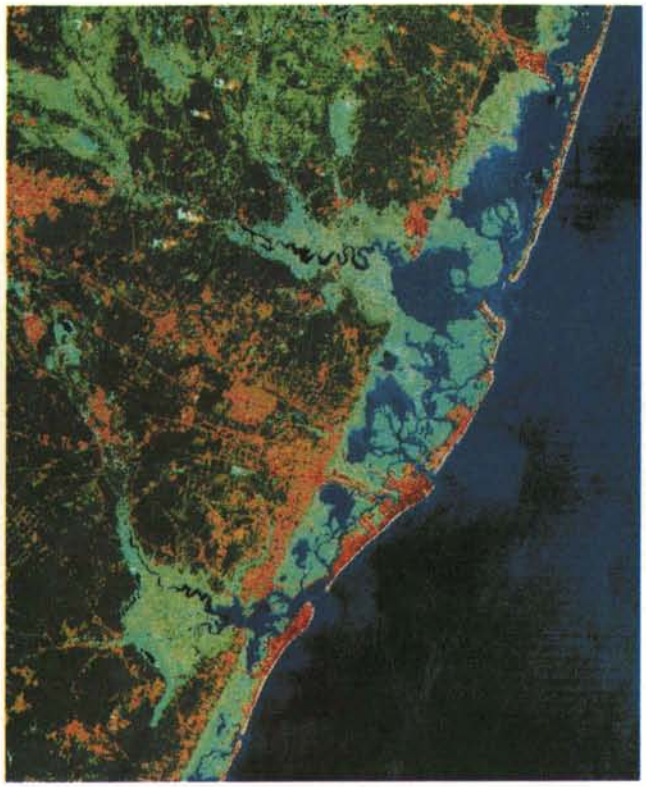
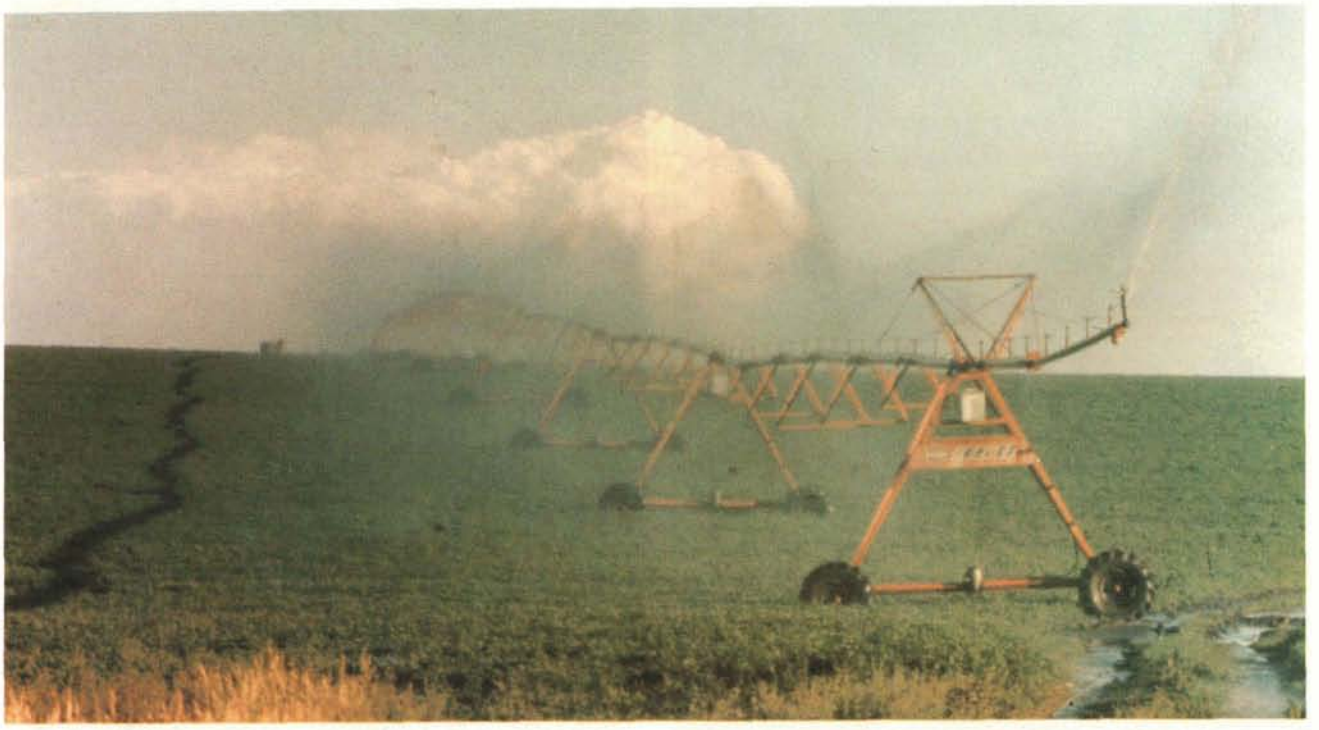


Land Cover Survey

In cooperation with the New Jersey Department of Environmental Protection and the Cape May County Planning Board, NASA is demonstrating how Landsat-derived information can be integrated into a geographic data base as a tool for guiding residential development decisions in the county. Satellite land cover data delineates existing development together with the location and extent of such environmentally-sensitive areas as wetlands, dune fields, beaches and unique vegetation communities. From this information, county officials can decide which areas are available for development and which are unsuitable.

The accompanying illustrations exemplify the type of information Landsat provides. At left is an enhanced Landsat image of the southern New Jersey coastline; it is centered around Atlantic City, north of Cape May County, but is typical of the Cape May application. The false color scene shows the great extent of vegetation, from salt marsh (brown tones) to pineland (bright red). Atlantic City and other developed zones are evident as blue gray areas along the coastal barrier islands.

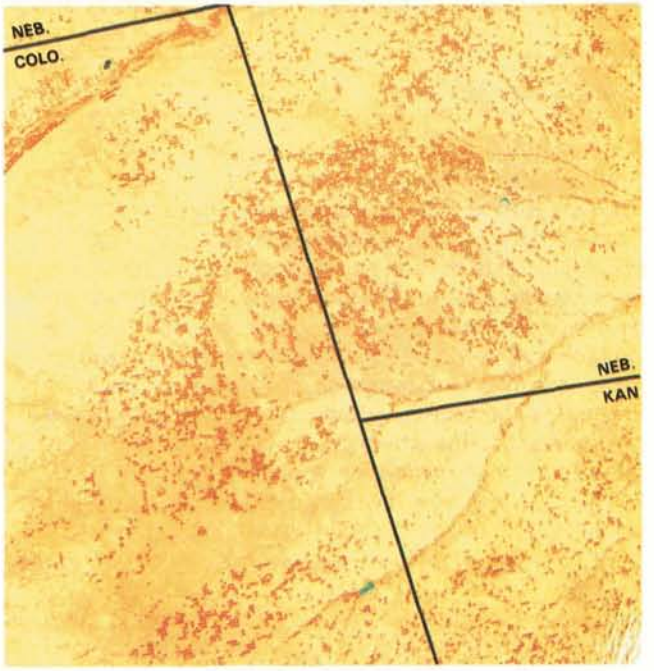
The illustration at right is a computer-aided classification of the data supplied by Landsat. It shows 38 different types of land cover. Among those of particular interest to county planners are urban areas (red, with the deepest red corresponding to highest density); forest land (green, with darker shades indicating greatest density); and the blue gray marsh areas, showing the degree to which water availability influences the distribution of plant species (the bluer the color, the more water is needed for species survival). The map was prepared by NASA's Eastern Regional Remote Sensing Applications Center and state/county authorities.



Irrigation Inventory

State agencies in Nebraska are making use of Landsat technology to assess the impact on water and fuel resources of the very rapid growth in the number of irrigation systems for the state's cropland. More than 80 percent of the increase has been in new installations of center pivot systems such as the one shown above. The average center pivot covers about 133 acres and uses more than 400,000 gallons of water a year for each acre. Thus, it is important that state planners know how many center pivots are being installed annually, to determine how much water is being expended from a drought-lowered water table in case the need arises for water allocation. Fuel to operate the center pivot system amounts to about 50 gallons per acre/year, so agencies concerned with fuel allocation and distribution also need information on the number of new installations. Irrigation growth affects several other state planning functions.

With NASA support, the University of Nebraska developed an accurate but inexpensive center pivot inventory technique based on Landsat imagery. The accompanying Landsat-derived map (right) shows how satellite data can be interpreted to produce a cropland picture in which center pivot systems (orange dots) stand out in contrast to surrounding terrain. With multiple images, resources engineers can inventory the entire state in only 150 man hours with an accuracy of about 95 percent. The University of Nebraska and the Nebraska Natural Resources Commission regularly update inventories and annually publish a statewide map showing—county by county—the yearly increase in center pivots, the cumulative total and an estimate of acreage under irrigation.

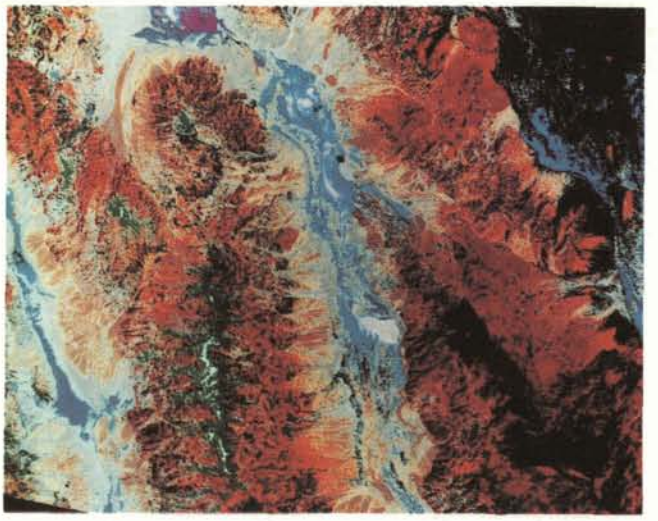


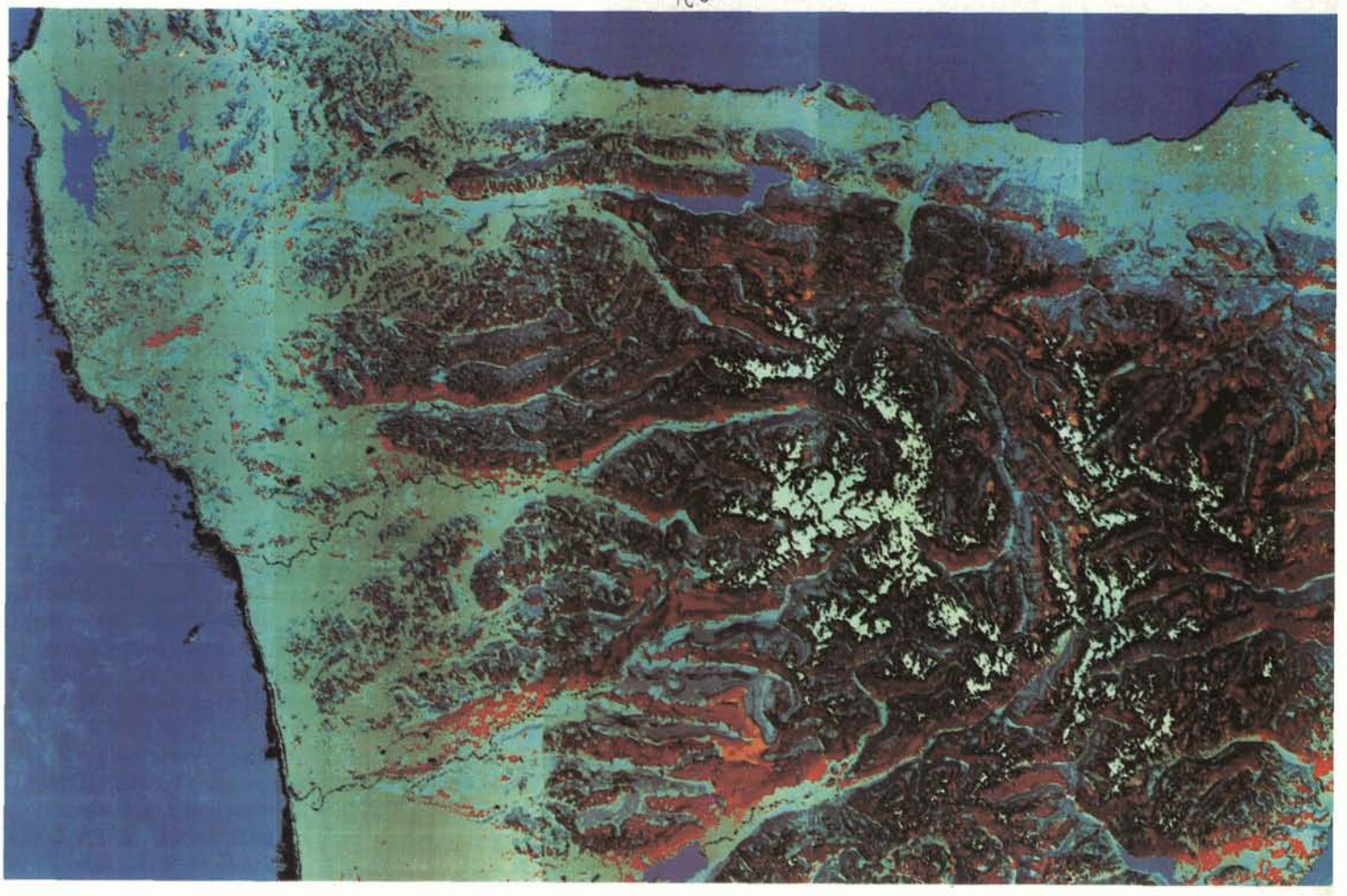
Parkland Survey

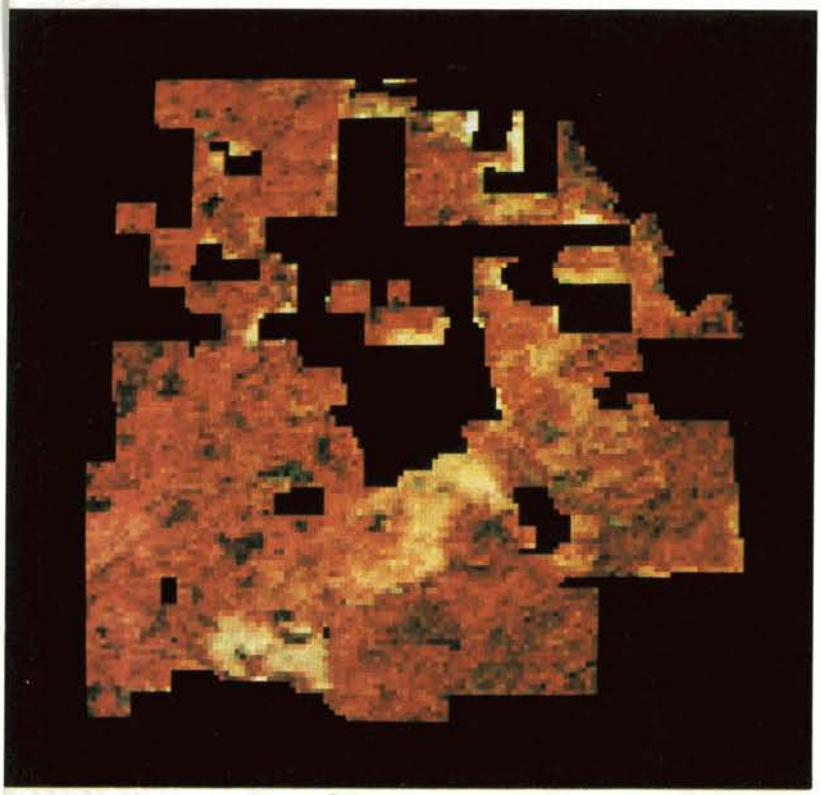
For effective management of some 300 park areas in the United States, the National Park Service (NPS) needs periodically-updated information on the various types of land cover within its park system. Such information is often difficult to obtain, due to access problems and the vast acreage to be inventoried. Thus, NPS' Denver Service Center and NASA's National Space Technology Laboratories are cooperating in development of a Landsat-aided automated inventory/monitoring system for acquiring the requisite information. In a demonstration project, Landsat data was combined with data from other sources to produce land cover maps of Shenandoah National Park in Virginia, Death Valley National Monument in California/Nevada, and Olympic National Park in Washington.

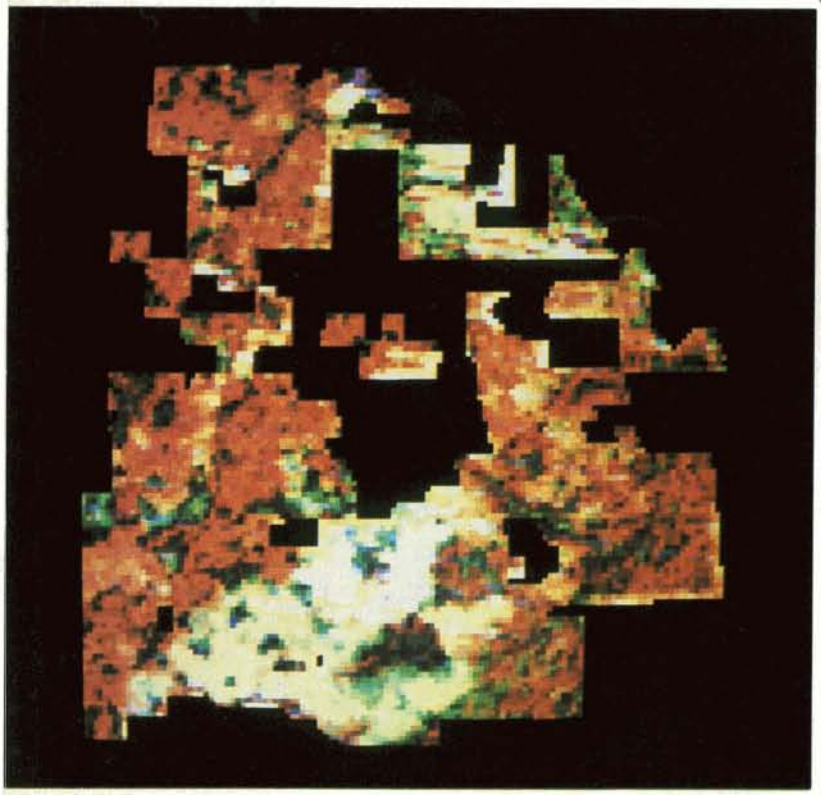
An example of the type of information available to NPS is the illustration at right, a color-coded classification of Death Valley National Monument. Each color represents a type of land cover, such as salt, silt, sand, bedrock, volcanic rock, or various kinds of vegetation. This information is useful in a number of ways; for instance, vegetation type and density aids assessment of an area's ability to support wildlife.

At Olympic National Park, Landsat-derived land cover information—along with terrain data supplied by the National Cartographic Information Center—was used to produce the fire hazard model shown below, an aid to planning fire prevention and control measures. The different colors represent degrees of fire hazard, based on such considerations as the amount and type of vegetation, elevation above sea level, steepness of slope and the terrain situation with respect to prevailing winds. The deep brown and reddish colors indicate areas of greatest hazard.







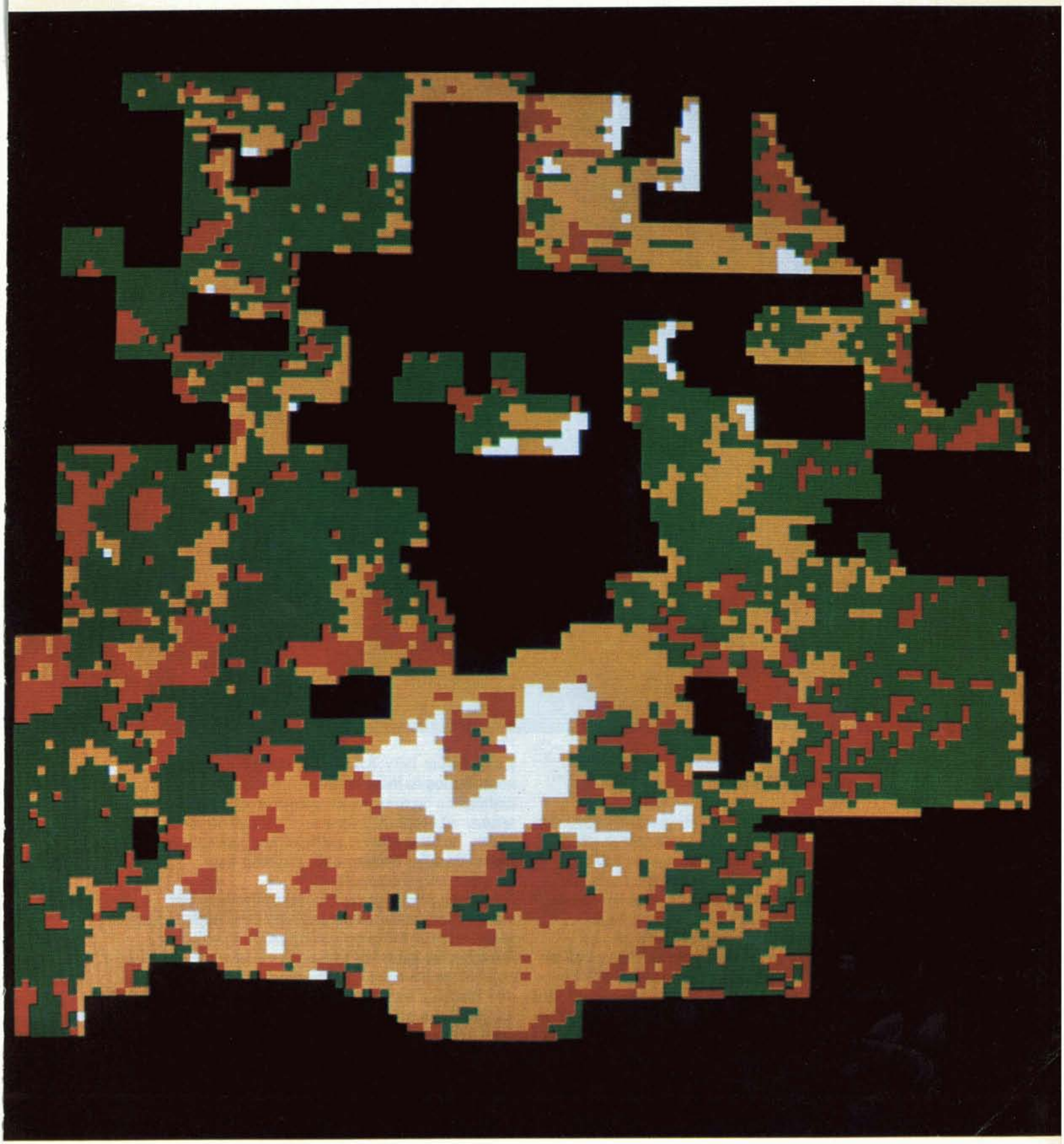


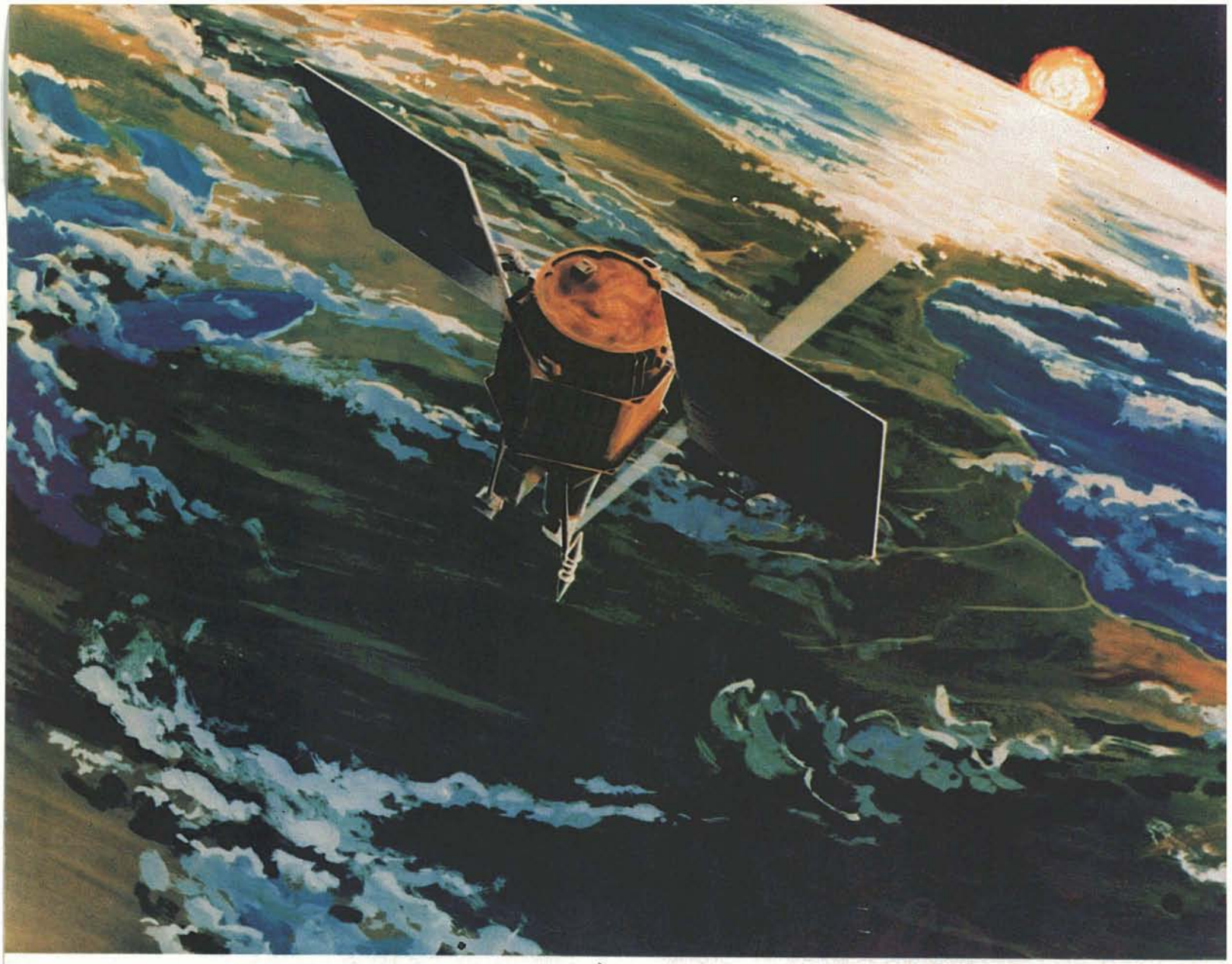
Forest Management System

The demand for forest products is expected to more than double by the end of the century, due to expanding population and greater per capita consumption of wood-base products. At the same time, the forest land base is decreasing in some parts of the country as a result of growing land use for such other purposes as recreation, transportation, industrial facilities and urban expansion. These factors combine to increase the need for timely, accurate information on which commercial forest managers can make sound decisions on such matters as harvest timing, change occurrences, wood supply, land acquisition, financial projection and long range planning. To improve information availability, a new Forest Resource Information System (FRIS) integrates satellite remote sensing technology with existing forest data bases. A FRIS demonstration was successfully concluded last year; it represented a three-year cooperative effort involving Johnson Space Center, the Purdue University Laboratory for Applications of Remote Sensing, and the Southern Timberlands Division of St. Regis Paper Company, Jacksonville, Florida.

Traditionally, forest managers have relied on aerial photography as a basis for ground data collection and development of management maps. These maps, plus tabular inventory data, comprise the primary management tool—but establishment and updating of this data base is very labor intensive and time consuming. FRIS combines map, inventory and Landsat information in a single computerized data base. Adding Landsat data provides new informational dimensions: complete, more accurate and more readily updatable data for planning purposes.

The FRIS demonstration was conducted in six southern states where St. Regis Paper Company owns 2.3 million acres. The illustrations show one type of information available from Landsat data: periodic and repeat coverage for monitoring forest changes. At upper left is a color infrared composite image prepared from data collected in December 1977 of St. Regis property in northeastern Florida. The lower left image was made 14 months later. The two images were digitally overlaid to produce the classification map at right, which details the changes that occurred between the two dates. Note the white crescent-shaped area in lower center of the latter illustration. The color key tells forest managers that tree cutting was in progress when the 1977 data was collected and that by February 1979 the entire area had been cut and the site prepared for replanting. Evaluation of subsequent data would show the progression of the newly established pine plantation. In the map, green represents dense pine stands, tan is young or sparse pine, and red is hardwood bottomlands; the black area at top center is land not owned by St. Regis. The results of the FRIS demonstration were sufficiently encouraging that St. Regis has invested in its own remote sensing data processing facility at Jacksonville. The entire forest industry stands to benefit because the technology is available to other companies.





Stratosphere Investigation

The Stratospheric Aerosol and Gas Experiment (SAGE) spacecraft shown is playing an important role in a broad investigation of the stratosphere, the region of Earth's atmosphere beginning at an altitude of eight miles and extending to approximately 30 miles. A vital but fragile element of Earth's environment, the stratosphere contains an ozone layer that protects Earth and its inhabitants from much of the Sun's ultraviolet radiation. Additionally, a stratospheric concentration of aerosols—tiny solid particles or liquid droplets—acts as a filter to control the amount of sunlight that reaches Earth's surface or is reflected back to space. Changes in aerosol concentration may cause changes in Earth's climate with important implications for agriculture.

Prompted by growing worldwide concern for the environmental quality of the stratosphere, NASA and other organizations are conducting studies—in laboratories, balloons, aircraft and satellites—to determine whether the stratosphere is adversely affected by man's industrial and technological activities.

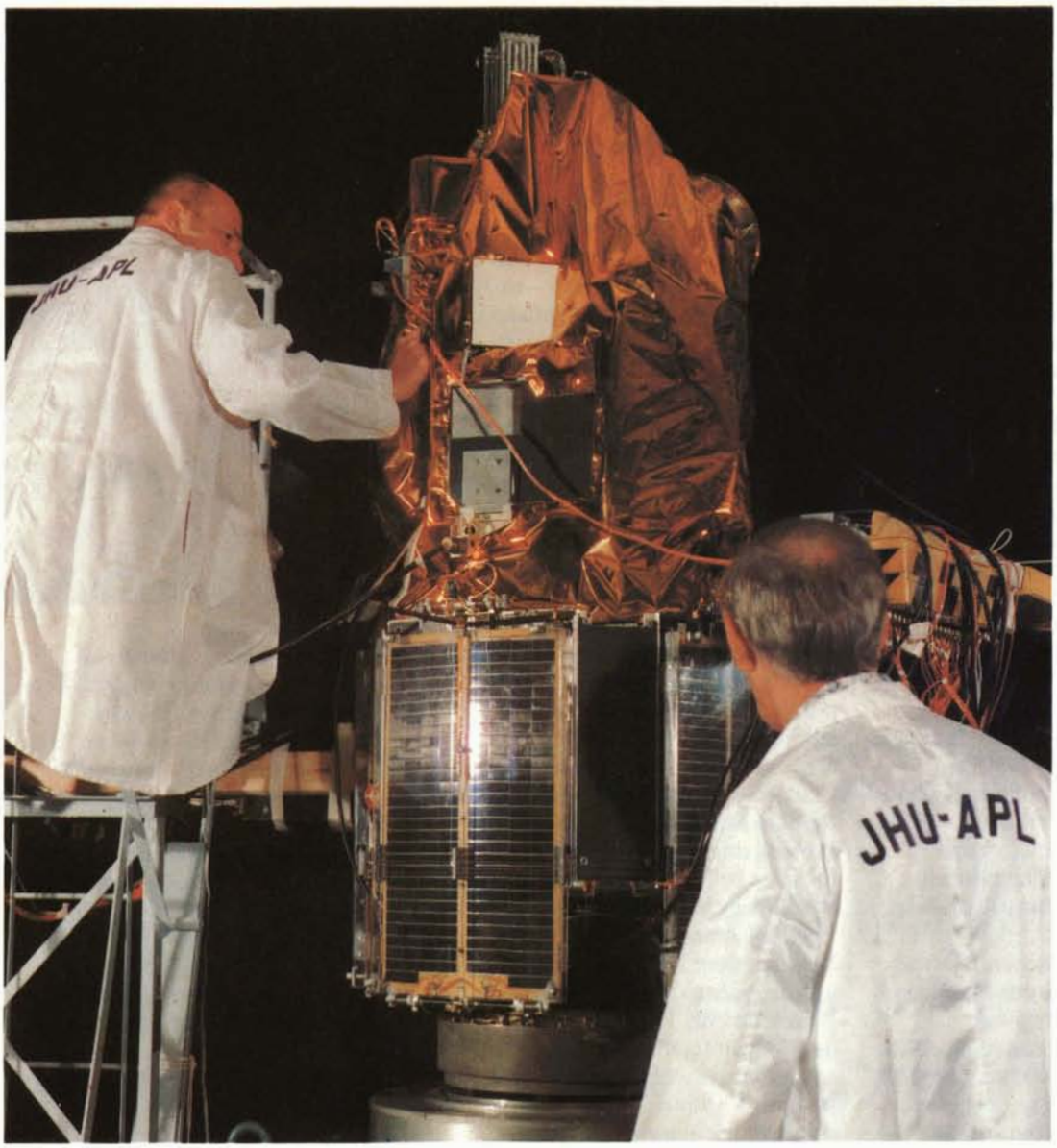
Launched in 1979, SAGE is making a significant contribution to these studies by providing long-term global data on ozone and aerosol levels. The SAGE spacecraft employs a device called a photometer to "look" at atmospheric particles and gases against the bright solar background, enabling high accuracy measurements.

Investigators also seek to determine how the stratosphere reacts to natural injections of particles and gases, such as those caused by erupting volcanoes. Fortuitously launched in time to monitor the eruptions of two volcanoes—the Caribbean's La Soufrière in 1979 and Washington's Mount Saint Helens in 1980—SAGE has contributed importantly in this area of study. These eruptions provided unexpected opportunities to measure abrupt volcano-caused changes in stratospheric aerosols and to map the dispersion of volcanic ash and gas. Such information is valuable to radiation balance investigations and to the study of how atmospheric pollutants might be transported globally. The SAGE project is managed by Goddard Space Flight Center; Langley Research Center has responsibility for instrumentation and science activities.

Magnetic Field Satellite

The Magsat satellite, shown before launch, concluded work last summer after a highly productive 225 days in orbit, during which the spacecraft's instruments acquired volumes of new and important data about Earth's magnetic field. The information is being used principally by the U.S. Geological Survey for updating magnetic field charts and maps used in marine and aerial navigation; as an aid to geological prospecting by providing a current background field model; and as an indicator of crustal anomalies for resource assessment study. Magsat's findings are also being studied by scientists of nine nations, who are investigating areas wherein Earth's dynamic behavior is influenced by terrestrial magnetism.

Magsat data enabled preparation of extremely accurate models and maps delineating regions of the Earth where abnormal magnetic intensities exist. It is believed that these anomalies are related to movement of the Earth's crust; thus, magnetic anomaly maps may provide clues to geologists searching for new mineral and petroleum deposits. The Magsat project is managed by Goddard Space Flight Center; the spacecraft was built by the Johns Hopkins Applied Physics Laboratory.



Research for Energy

Applying its expertise to the search for new ways to produce and conserve energy, NASA is playing a major role in a vital national program

In the great majority of all spacecraft launched thus far, power for on-board equipment has been supplied by solar cells which convert sunlight directly into electricity. Photovoltaic conversion, as the process is known, has proved effective and highly reliable in more than two decades of space operations. It can work just as effectively on Earth. In fact, it has already demonstrated its potential—in more than a thousand specialized Earth applications—as a promising alternative energy source that could significantly alleviate U.S. dependence on foreign oil.

Photovoltaic conversion offers many advantages. The solar cell, which has no moving parts, is simple and reliable; its only "fuel" is sunlight; it emits no polluting exhaust or noise; and its material—silicon—is one of Earth's most abundant elements. The primary obstacle to widespread use of this energy system is cost.

In some earlier spacecraft, solar cell arrays cost hundreds of dollars per watt of electrical power produced. Research has reduced the cost to less than ten dollars per watt, acceptable in space use because there is little choice, but still too expensive for widespread Earth applications except those where no conventional power source exists—for example, automated weather stations in remote areas or sea-based navigational buoys. To promote broad adoption of civil-use photovoltaic systems, the Department of Energy (DoE) is conducting research aimed at further lowering the cost—by 1986—to 70 cents per peak watt (1980 dollars). That would open the door to countless industrial, residential and commercial applications.

Two NASA centers have key roles in the DoE program. Jet Propulsion Laboratory (JPL) is the lead center for the Photovoltaic Technology Development and Application Program and manager of the Low Cost Solar Array Project. JPL works with industry, academic and government organizations to reduce costs by improving cell design and production processes, and to stimulate the growth of the solar array industry. Lewis Research Center manages DoE's Photovoltaic Remote Stand-Alone Applications Project, intended to build a market for solar cells by demonstrating their advantages in practical applications. Lewis also manages the Photovoltaic Development and Support Program for the Agency for International Development. This effort involves demonstrating the suitability and cost competitiveness of solar cell systems for rural applications in developing countries.

The solar cell is a thin wafer of crystalline silicon made in two layers, with narrow metal strips plated on the top and a metal surface on the bottom. When the cell is exposed to sunlight, electrons are dislodged within the crystal. They

The solar cell arrays shown are representative of many projects in a Department of Energy/NASA program involving development, test and demonstration of photovoltaic systems which convert sunlight directly into electricity. Shown above is radio station WBNO, Bryan, Ohio, whose daytime AM radio operation is powered by a 500-watt system developed by Massachusetts Institute of Technology's Lincoln Laboratory, a member of the DoE/NASA team. At right is a multimodule array which generates 60,000 watts to power equipment at Laguna Air Force Station, California. At upper right is the largest photovoltaic system in operation, a 100,000-watt array also developed by Lincoln Laboratory; located at the Natural Bridges National Monument in Utah, it supplies 90 percent of the park's energy needs.

migrate into the metal strips of the top layer and out through an electrical circuit, forming a current; then they travel back to the cell through the lower metal surface. This process goes on continuously, maintaining a constant current. The output of the individual cell is small, so many solar cells are connected in panels or modules to produce a practical voltage level.

Jet Propulsion Laboratory is exploring a number of ways to cut costs, including means of increasing the solar cell's efficiency, extending its lifetime and substituting a lower grade silicon for the expensive, highly-purified form currently used. Wafer production is now accomplished by "growing" long cylindrical crystals and slicing them like salami with a special saw, a wasteful and time consuming process. Advanced production methods being considered would eliminate waste by growing wafers in long ribbons or large sheets. Once the wafer is produced, it must be made into a semiconductor by addition of the metal contacts. That now requires as many as 62 steps, which could be cut sharply by computer-controlled fabrication or other automation techniques. Finally, for low-cost mass production, solar arrays must be manufactured in standard modules and assembled to fit the user's need at the site. Work is under way on standardized designs to provide maximum applicability and to minimize expensive custom designing and assembly.

NASA's long experience in photovoltaic conversion for spacecraft electric power is an example of how the agency's special capabilities can be turned to advantage in the national energy quest. Other examples include NASA's aerospace-acquired expertise in such areas as turbine engines, propeller and rotor systems, batteries, fuels, lubricants and seals, all of which provide a technology base for improving efficiency and reducing fuel consumption of non-aerospace machines. Further, NASA's demanding aerospace programs have generated expertise of a general nature in an exceptional range of scientific and technological disciplines. This enables assembly of teams of highly-skilled technologists whose collective talents can be brought to bear on virtually any research assignment—for example, finding ways to increase production in coal mining operations or developing processes for converting coal into clean gaseous or liquid fuels, work only remotely related to aerospace technology.

Other areas of NASA energy research, development and demonstration include systems for wind energy, solar heating/cooling and thermal electric power, ground propulsion, more fuel-efficient industrial turbines, new ways of storing excess energy, and preliminary work on a proposed Satellite Power System that offers potential for generating Earth-use electricity. Some of this effort is NASA-funded; more often, NASA performs research and development for the Department of Energy or other government agencies on a reimbursable funding basis. Such employment of NASA's special talents is paying the nation a dividend on its aerospace investment and simultaneously broadening NASA's competence for future aerospace research.

Solar Heating/Cooling

The solar arrays pictured provide heat input for an energy system at the University of Kansas used to heat and cool an apartment building for married students, to furnish hot water for a laundry serving 288 student families, and to supply supplementary power to the apartment's electrical system. It was the first application of an advanced "Rankine cycle" system developed by Honeywell Inc. under NASA contract.

The Kansas installation is one of more than 1,000 residential, commercial and federal government demonstration facilities in a Department of Energy (DoE) program aimed at expanding national experience, increasing consumer confidence and encouraging more rapid commercialization of solar heating/cooling systems. Marshall Space Flight Center has multiple assignments in the DoE program, including development of advanced systems and management of practical demonstrations. Marshall assisted in development of a national solar heating/cooling data bank by installing sensors at selected demonstration sites, monitoring equipment performance, analyzing results and storing the data to build an informational base for future use.

Marshall's responsibilities were expanded last year when the center was assigned technical management of DoE's Solar Federal Buildings Program. Intended to establish a government leadership role in expanded use of solar energy, the program calls for installation of more than 800 new solar heating/cooling systems in federal buildings throughout the United States.

30

Solar Thermal Power

The large saucer-like objects shown are parabolic dish concentrators whose reflective surfaces collect and focus sunlight for generating electrical power or high temperature industrial-use process heat. The dish is composed of a number of concave mirrors angled so that reflected radiation is concentrated at a focal point—the rod-supported center structure in the photo. At the focal point is a receiver (not shown) which captures the concentrated radiation and converts it to a "working fluid," such as hot gas. The heated fluid is put to work in one of two ways. In an electricity-producing module, the fluid goes to a power conversion unit mounted on the receiver, where it drives an engine mechanically linked to an electric generator. In an industrial heat module, the fluid is piped from the receiver into an energy transport network on the ground, then distributed to industrial equipment. Either type of module has an automatic tracking system to keep the reflecting dish directed toward the Sun.

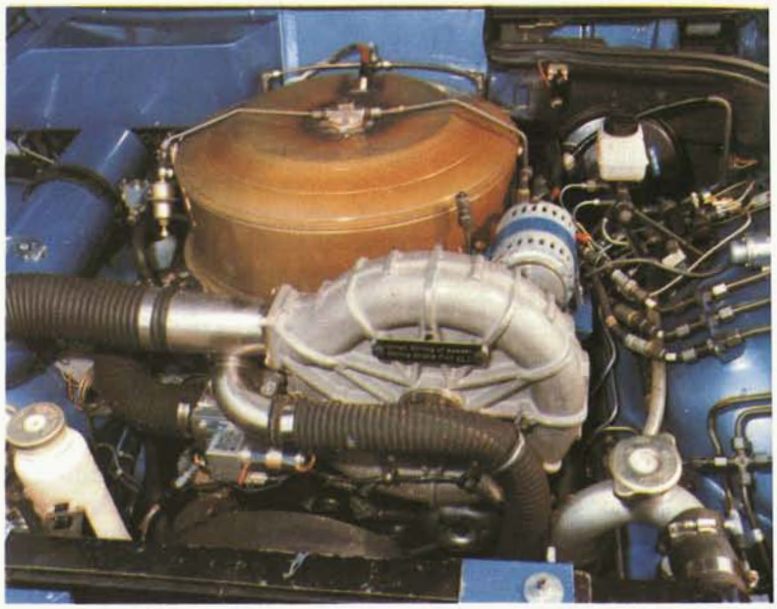
In this Department of Energy program, Jet Propulsion Laboratory and a group of industry contractors are developing several types of concentrators; Lewis Research Center, also working with contractors, is developing associated power conversion systems. Testing is conducted at the NASA Parabolic Dish Test Site, Edwards, California.

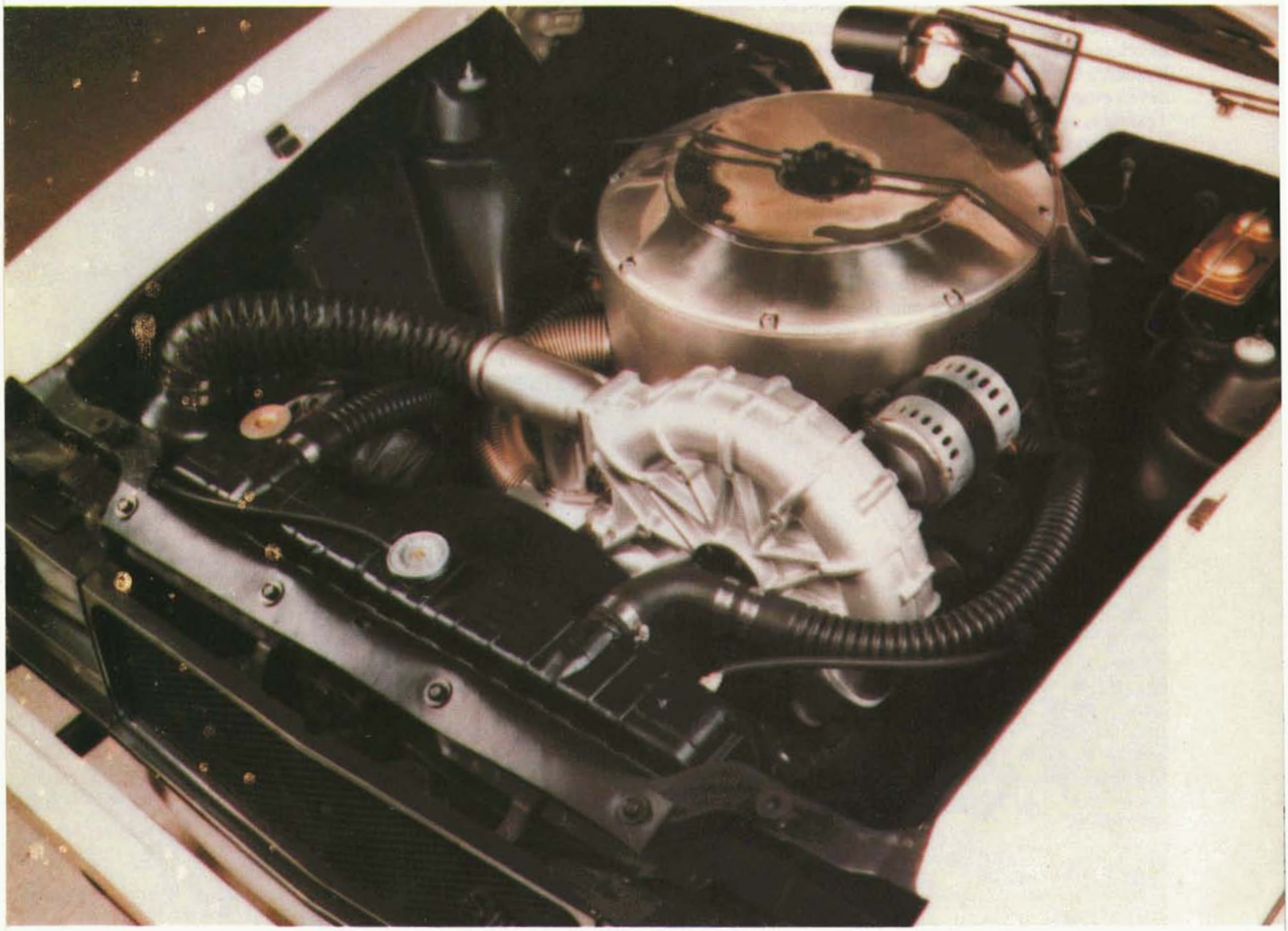
Point-focus modules offer capacities measured in a few tens of kilowatts. They could be used individually by small communities, factories or farms, or they could be employed in multi-module groups to meet the greater heat/electricity needs of utilities or large industrial facilities—a million watts or more. The program envisions availability in the mid-1980s of advanced, cost-competitive, mass-producible modules.

31

Ground Propulsion

At right is a laboratory research Stirling engine produced by United Stirling of Sweden (USS). It served as a basis for an advanced automotive Stirling propulsion system being developed by USS for Mechanical Technology Incorporated (MTI), Latham, New York, as part of the Department of Energy/NASA Heat Engine Systems Program. Like conventional engines, the Stirling burns an air/fuel mixture to drive pistons and thus transmit power to the auto's wheels. The Stirling differs from conventional internal combustion engines in that it depends upon an external, continuous combustion heater head located outside the cylinders. The Stirling system offers many important advantages, chief among them lower fuel consumption—theoretically 30-50 percent better than the equivalent internal combustion engine—and multi-fuel capability, meaning the ability to use most liquid or gaseous fuels, such as gasoline, kerosene, alcohol, diesel fuel, butane and others. This





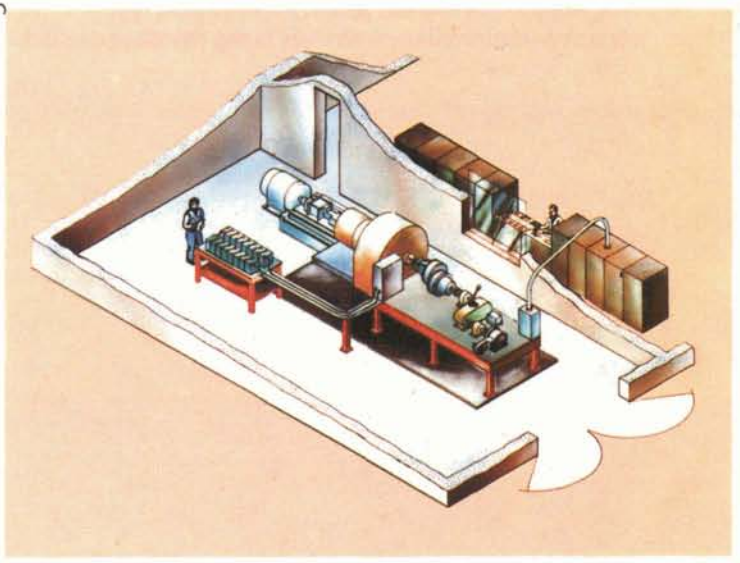
capability will become increasingly important as synthetic fuels become available.

The laboratory engine pictured was MTI's initial experimental engine. An improved version of the same engine (left) was installed and tested in a 1979 American Motors Spirit (above). A more advanced Stirling system is being developed under a program managed by MTI; it will be vehicle-tested beginning in 1982. Goal of the program is development—by 1984—of an experimental engine system that will provide at least a 30 percent fuel-efficiency improvement over current conventional engines, together with multi-fuel capability and significant reduction in emissions.

Lewis Research Center manages the Heat Engine Systems Program which, in addition to Stirling engine development, also focuses on development of technology for an advanced experimental automotive gas turbine engine. The gas turbine offers advantages similar to those of the Stirling: better fuel economy, multi-fuel capability and reduced emissions.

Lewis also manages for the Department of Energy the Electric and Hybrid Vehicle Propulsion Research and Development Program. This program is aimed at advancing propulsion technology for electric and hybrid vehicles (part electric, part fuel-burning) to the point where they can begin to compete with existing transportation systems. Electric and hybrid cars are important to national energy conservation because their energy sources could be provided by utilities using coal or nuclear energy rather than petroleum.

A unique and valuable facility for development of electric/hybrid vehicles is Lewis' Road Load Simulator shown below. Developed by the center and placed in operation last year, the simulator allows test of propulsion systems and components under controlled, repeatable conditions; this reduces testing time and cost and provides more accurate results than can be obtained by vehicle testing on track or road. In the drawing, the "driver" at upper right operates a computerized programmable controller which simulates vehicle weight, tire types, aerodynamic drag and other variables; it also varies drive torques, speeds, loadings and running times. The propulsion system being tested and its battery rack for electric power are shown in center photo.



Wind Energy Systems

Shown above is the world's largest, highest capacity wind turbine installation, a three unit, 7.5 million watt system located in the Goodnoe Hills along the Columbia River Gorge in Washington. To be completed this year and operated by the Bonneville Power Administration (BPA), the electricity-generating "windmills" were designed and built by Boeing Engineering and Construction Company in a Department of Energy/NASA program aimed at development of advanced technology, cost-competitive, large wind turbines as alternative power sources; Lewis Research Center manages the program. Each of the Goodnoe Hills turbines employs a 300-foot-diameter rotor blade to convert wind energy into 2.5 million watts of electric power. Their combined output, which will be fed into the BPA network, is equivalent to the amount of electric power needed to supply 2,000 to 3,000 average homes.

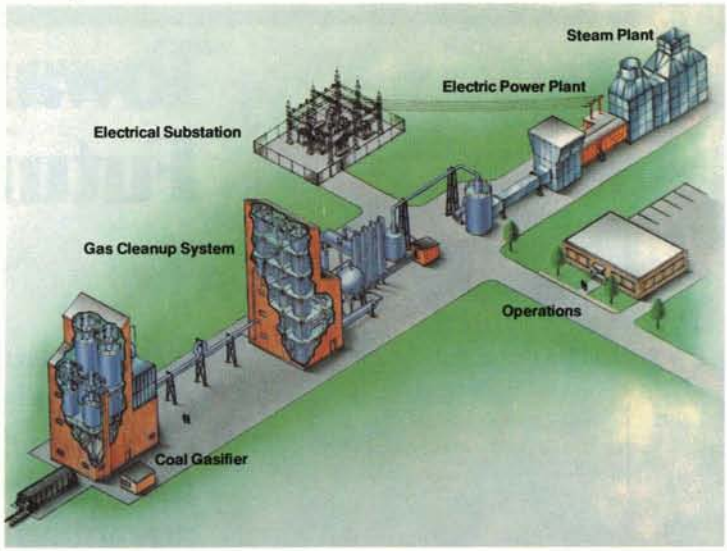
A single wind turbine generator of even larger capacity—four million watts—is being developed under Lewis Research Center management for the Department of the Interior's Water and Power Resources Service. Designed and built by Hamilton Standard Division of United Technologies, it is being installed near Medicine Bow, Wyoming and is expected to be in operation late this year. Two other four-million-watt machines are being developed under Department of Energy sponsorship, one designed by Boeing, the other by General Electric Company. They are prototypes of machines intended to feed large-scale electricity to utility companies. The schedule calls for operation in 1983.

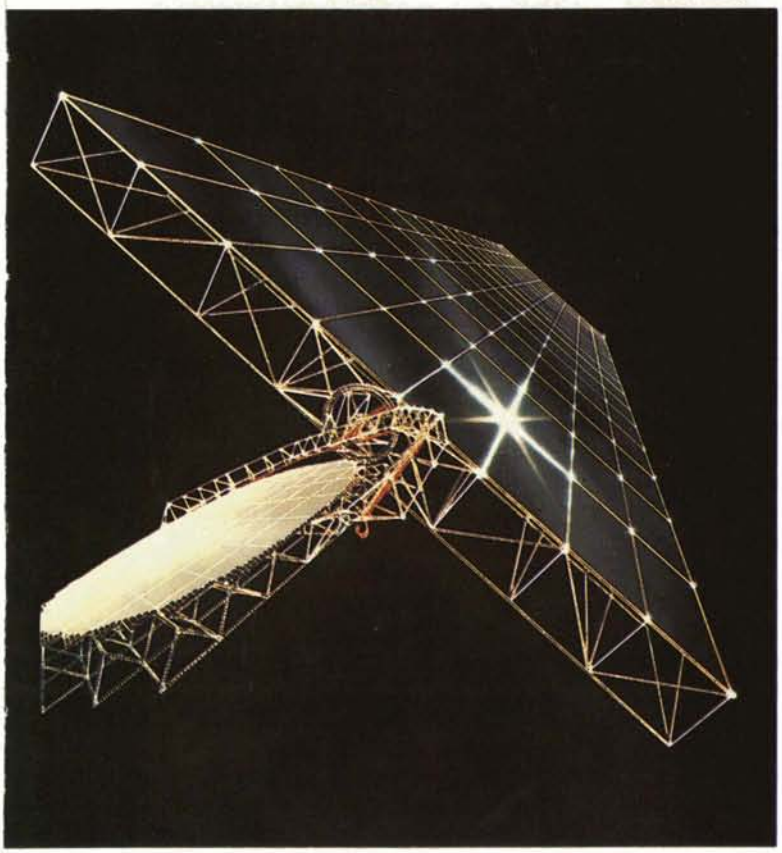
The DoE/NASA wind energy program involves test and demonstration of a number of differently-sized turbines in different geographical locations under varying wind conditions. A two million watt system is operating at Boone, North Carolina. At right above is a Westinghouse-built 200,000-watt unit installed last year on the island of Oahu, Hawaii. Three similar machines are located in Clayton, New Mexico; Block Island, Rhode Island; and Culebra, Puerto Rico. Also in development by DoE are small wind turbines that could be used by individual homes and farms.

Coal-fired Powerplant

Lewis Research Center is studying a new type of electric powerplant that would turn "dirty" high-sulfur coal into clean-burning gas—and provide a bonus through a process known as "cogeneration," in which the normally-wasted powerplant heat is put to work. The plant could be virtually pollution-free and its energy yield per ton of coal could be approximately double that of a conventional power generating system. A study conducted for Lewis by Davy McKee Corporation, a Cleveland-based engineering firm, concluded that the system is technically feasible; however, considerable engineering development will be required.

The accompanying illustration shows the four-step coal gasification/cogeneration process. In the gasifier—something like a giant pressure cooker—coal reacts with air or oxygen at high temperature to produce a combustible fuel gas. The gas is routed through a cleanup system, where suspended particles and chemical pollutants are removed. The cleaned fuel is burned in a gas turbine driving an electricity-producing generator. The turbine's hot exhaust is then utilized to generate steam for use in laboratories and other test facilities. Successful development of this technology would substantially benefit those areas of the U.S.—mostly the eastern half—where high-sulfur coal is the predominant variety. This is one of several coal research projects being conducted for the Department of Energy by Lewis Research Center, Marshall Space Flight Center and Jet Propulsion Laboratory.





Satellite Power System

Looking toward non-petroleum means of meeting future energy needs, NASA and the Department of Energy are studying the potential of the Satellite Power System. Considered technically feasible though technologically demanding, the concept envisions a network of satellites generating a significant portion of the nation's power requirement by drawing upon the abundant energy of the Sun. Each satellite would produce power sufficient to serve a large city. Assembled in orbit from materials delivered by space transportation vehicles, the individual satellite would be a miles-long platform containing a "farm" of solar cells or alternative devices capable of transforming sunlight into electricity. The electricity would be converted to microwaves, beamed to Earth receivers and reconverted to electricity for use by consumers. One conceptual design is shown at left.

Toward Future Flight

NASA's aeronautical research program is providing solutions to current aviation problems and new technology for tomorrow's advanced aircraft

Last year, the XV-15 research aircraft reached a speed of 350 miles per hour. Ordinarily such a speed would hardly merit mention, but in this instance it was a milestone accomplishment because the XV-15 is not an ordinary airplane. The craft can take off and land vertically, hover, or fly sideways or rearward. A convertible rotorcraft which combines the unique capabilities of the helicopter with the greater forward speed of the fixed-wing airplane, the versatile XV-15 is an experimental forerunner of a new type of aircraft that could bring about significant improvement in tomorrow's air transport system.

Built by Bell Helicopter Textron, Fort Worth, Texas, under the joint sponsorship of NASA and the U.S. Army Research and Technology Laboratories, the XV-15 is formally known as the Tilt Rotor Research Aircraft. The V/STOL (Vertical/ Short TakeOff and Landing) craft has two large rotors which provide vertical lift; once airborne, the rotors tilt forward to become propellers for cruise flight. There are two such vehicles undergoing test, one at Ames Research Center and the other at Dryden Flight Research Center. Although the XV-15 has demonstrated basic capabilities in vertical, transition and forward flight, extensive additional testing is necessary to verify performance under a variety of conditions.

The tilting rotor concept embodied in the XV-15 is regarded as a promising candidate for future short-haul air transportation applications, both military and civil. In military service, such a craft could serve as a troop/supply transport capable of landing in forward areas where there are no runways; as a reconnaissance vehicle; as a carrier-based patrol plane, or as a rescue aircraft. The tilt-rotor V/STOL has similarly broad potential in civil air service, operating as a commuter liner from small, close-to-city heliports—thereby diverting traffic from large "hub" terminals and easing airport congestion, a problem of ever-increasing dimension for the U.S. air transportation system. The tilt-rotor craft also offers special utility for hauling workers and equipment to offshore oil rigs at speeds and ranges beyond the capabilities of helicopters.

NASA is exploring other avenues toward development of technology for tomorrow's short-haul air transportation system, for example, advanced helicopter rotor systems, compound helicopters with wings and auxiliary propulsion for forward flight, and V/STOL systems other than the XV-15. This effort represents one facet of NASA's comprehensive aeronautical research program, which is providing dividends to the nation in several forms: making flight safer for all who

The NASA/Army XV-15 Tilt Rotor Research Aircraft combines helicopter-like performance with cruise speeds twice those of modern helicopters. For takeoff, the craft's rotors operate in the horizontal plane to provide vertical lift (bottom photo); then they tilt forward (center) to become propellers for cruise flight (left).

41

42

fly; improving the environmental characteristics of aircraft; helping to restrain airline operating costs to the benefit of passengers, shippers and operators; and enhancing the competitive position of American plane builders in the international marketplace, at a time when export sales are becoming more and more important to the U.S. economy.

NASA's aeronautical research program has two main avenues. In one, researchers anticipate tomorrow's aviation needs and seek to develop applicable technology. The XV-15 and related short-haul vehicle programs are examples of this type of activity. Others include pursuit of advanced technology toward improving the performance, efficiency and environmental acceptability of general aviation planes, small transports, advanced subsonic jetliners, high-performance military aircraft and commercial supersonic cruise aircraft.

In the other general area of effort, NASA generates technology for solution of current and predictable aviation problems. The primary example is the Aircraft Energy Efficiency program, which focuses on curbing jetliner fuel consumption. This work embraces not only the obvious research target—the engine—but also improved aerodynamics, lighter aircraft structures and computerized flight control systems, all of which influence fuel expenditure. The results of this effort are already beginning to appear in operational airplanes and NASA has identified advanced technologies which could collectively halve fuel consumption when applied to newly designed aircraft. Energy efficiency research is also producing bonuses in noise abatement and reduced engine emissions.

In both of the main avenues of aeronautical research, and in a broad variety of ancillary projects, there is a common aim: greater safety provisions for all types of aircraft, exemplified by research in such areas as fire-resistant materials, collision avoidance, bad weather operations, stall/spin prevention and more crashworthy structures for improved protection of pilots and passengers.

Propulsive Lift

Shown landing on the aircraft carrier *USS Kitty Hawk*, the Quiet Short-haul Research Aircraft (QSRA) is a flight facility for research in terminal area operations at airports with short runways, an experimental pathfinder for future short-haul transports operating from close-to-city STOLports with minimal noise impact on the surrounding community. The QSRA was built by Boeing Aerospace Company under NASA contract.

The primary aim of the QSRA program—being conducted by Ames Research Center—is validation of a technique known as "propulsive lift," wherein the exhaust from the plane's four turbofan engines is used to gain extra lift. Engine fan air is directed across the upper surface of the specially-designed wings and flaps to create very high lift levels—as compared with current conventionally-configured aircraft—which permit steeper climbout and approach angles and low-speed, short-roll landings. In the 1980 *Kitty Hawk* tests, part of a NASA/Navy investigation of the application of propulsive lift technology to sea-based aircraft operations, the QSRA made 16 full-stop landings without the arresting gear normally used for carrier landings.

The QSRA's engines are soundproofed to muffle internal noise, and noise impact is further lessened by the fact that the sound of engine exhaust is diverted upward, away from listeners on the ground. These factors, together with the steeper climbout capability afforded by propulsive lift, sharply reduce the QSRA's noise impact. Although it is a relatively large aircraft (50,000 pounds), it can operate at lower noise levels than most small business jets.

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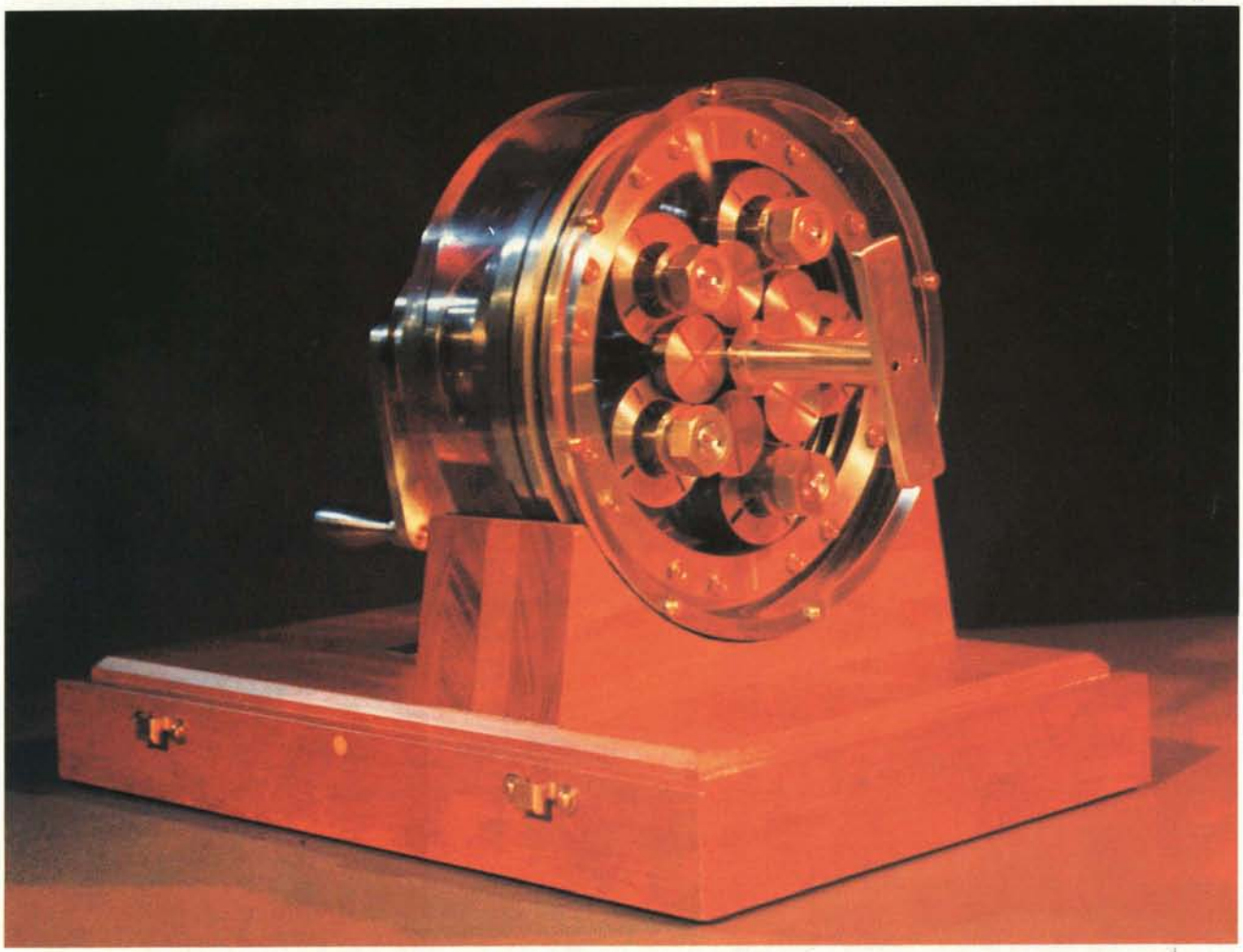


Traction Drive

Improved performance sought for the next generation of helicopters will require turbine power plants operating at higher speeds. A potential problem exists in that conventional gearing systems for transmission of power to the helicopter's main rotor may not be able to handle the high turbine speeds contemplated. So Lewis Research Center is developing an advanced power transmission system (model shown) which employs a series of toothless rollers instead of conventional toothed gears to transmit high power loads at high speed ratios. Called the Multiroller Traction Drive, the concept is based on an invention by Dr. Algirdis L. Nasvytis and incorporates a number of improvements resulting from eight years of research and testing at Lewis.

As a helicopter system, the Multiroller Traction Drive provides quiet, almost vibrationless transmission of power to the rotor. In this and other applications, it offers multiple advantages over conventionally-geared systems. It is lighter and smaller than conventional gear boxes; the absence of toothed gears make it easier and less expensive to manufacture; and because the rollers never actually touch each other—they are separated by a film of traction fluid—it is more reliable and less susceptible to wear. The Multiroller Traction Drive appears to be an attractive alternative to conventional gearing in many applications other than helicopters, including aircraft drives, rocket engine turbopumps, wind energy turbines, automotive engine drive trains and high speed industrial turbomachinery.

Pivoting Wing

The AD-1 manned minijet pictured represents a significant departure from conventional aircraft design in that its wing can be pivoted fore and aft to form oblique angles up to 60 degrees with the plane's fuselage. Weighing about one ton, the experimental craft represents an initial step toward validation of the concept that changing an airplane's wing angle in flight can provide greater aerodynamic efficiency at high speed while maintaining efficiency at lower speeds. For takeoff, landing and low speed cruise, the wing is perpendicular to the fuselage (top photo); as the airplane flies faster, pivoting the wing to oblique angles (lower photo) decreases air drag, permitting increased speed or longer range for the same fuel expenditure.

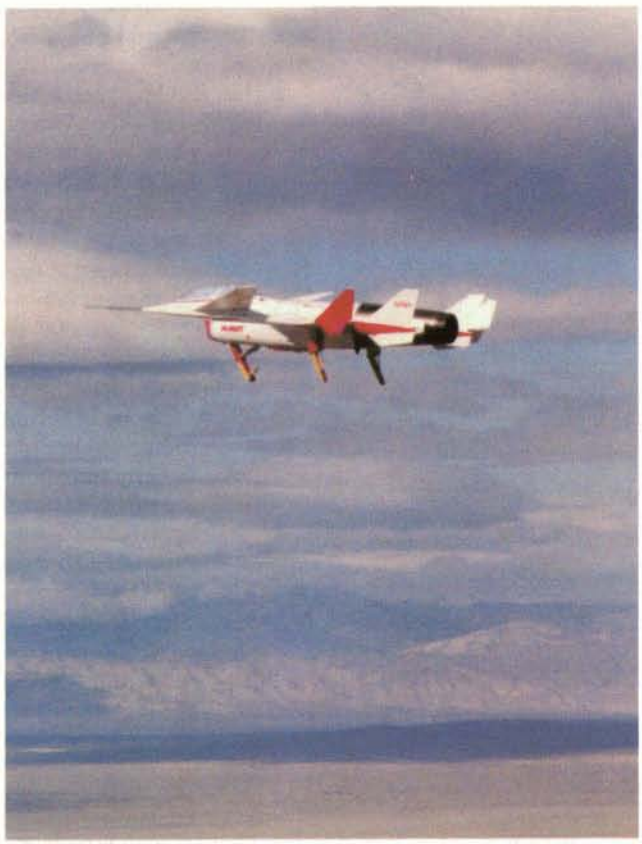
Limited to low speed operation, the AD-1 is intended only to demonstrate the ability to pivot the wing during flight and to study the fundamental aspects of piloting an oblique-wing aircraft. In 1980 tests, the miniplane was tested at wing angles up to 47 degrees. The "AD" designation stands for Ames/Dryden; Ames Research Center performed analytical and wind tunnel studies of the "scissor-wing" concept and Dryden Flight Research Center has been conducting flight tests since late 1979.

47

HiMAT

Undergoing flight test at Dryden Flight Research Center, the unmanned research aircraft shown—one of two built by Rockwell International—is called HiMAT, for Highly Maneuverable Aircraft Technology. It is part of a joint NASA/Air Force program involving demonstration of advanced technologies—in aerodynamics, structures, propulsion and flight controls—which may be incorporated in future military fighters. The HiMAT design includes a primary wing with tip-mounted winglets and a small forward "canard" wing; this combination of airfoils enhances maneuverability and controllability and gives HiMAT twice the turning capability of the most maneuverable fighters currently in operational service.

HiMAT was constructed in modular fashion, so that it can be easily modified to test new technologies emerging from research laboratories. The craft consists of a core vehicle—the fuselage, engine and basic subsystems—to which other components, such as different wing designs, can be added at minimal cost. Air-launched from a B-52 carrier plane, HiMAT is "flown" by a pilot in a ground-based cockpit. This NASA-developed remotely-piloted research vehicle concept allows high-risk flight testing without risk to pilots and reduces vehicle cost through elimination of the customary provisions for pilot occupancy and safety.

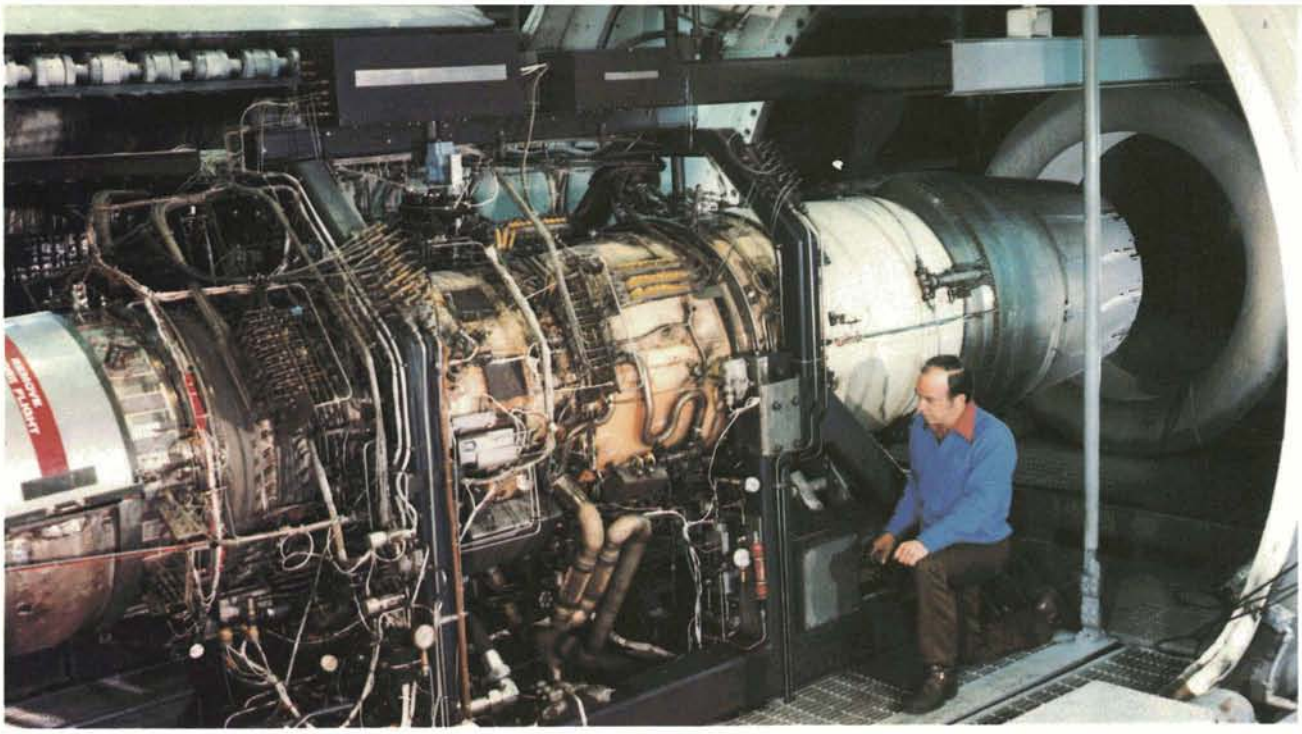


48

Laminar Flow Control

At low speed, the layer of air next to an airplane's skin—the "boundary layer"—flows smoothly over the plane's contours, a condition known as laminar flow. At higher speed—such as a jetliner's cruise speed—the boundary layer becomes turbulent, creating air drag that costs increased fuel expenditure. If laminar flow could be maintained at higher speeds, fuel savings of as much as 40 percent could be realized.

Toward that end, NASA is investigating two approaches to laminar flow control. The one represented by the accompanying photo is called the natural method; the wing of the airplane is coated with a plastic substance to form a supersmooth surface, which promotes laminar flow by reducing the friction between air molecules and the plane's skin. The other approach involves use of lightweight suction pumps to remove the turbulent air by drawing it through tiny apertures in the aircraft's skin. Laminar flow control investigations are part of NASA's Aircraft Energy Efficiency research and technology program, which seeks major fuel consumption reductions through advances in propulsion, aerodynamics, structures and flight control systems.



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Smart Carburetor

Advancing jet engine performance dictates need for an improved system for controlling the many variable conditions of engine operation, for example, fuel flow, air flow or compressor speed. Traditional mechanical controls are adequate for handling a small number of inputs, but future engines will require simultaneous control of as many as 10 to 15 engine operation variables. To meet this need, Lewis Research Center and the Air Force Aeropropulsion Laboratory are jointly developing a fully-computerized Multivariable Engine Control System for future jet aircraft. Nicknamed the "smart carburetor," the system is shown undergoing test at Lewis on a Pratt & Whitney F-100 turbofan engine. It promises greater responsiveness and engine efficiency, with added benefits of longer engine life and improved reliability. Heart of the system is a digital computer which continuously monitors engine operating conditions and manipulates engine inputs more precisely than existing control systems.

51

Clean, Quiet Engines

In the photo, Lewis Research Center engineers examine a model being readied for engine inlet testing in a NASA program known as QCSEE (Quiet, Clean Short-haul Experimental Engine). QCSEE tests indicated that advanced design techniques can reduce noise levels of jetliner powerplants well below that of the quietest engine now in civil transport service. Similarly, new combustor technology has sharply reduced emissions of the most troublesome air contaminants. Although QCSEE technology development focused on short-haul aircraft (300-500 miles range), Lewis' work is applicable to engines for larger commercial jetliners.

52

Stall/Spin Research

Shown being tested at Wallops Flight Center, this single-engine lightplane is a fully-instrumented research craft used in studies of the spin characteristics of general aviation aircraft, meaning all planes other than commercial airliners and military aircraft. The flight tests are part of a program conducted by Langley Research Center aimed at development of ways to prevent accident-causing stalls and spins. Based on data gathered in extensive spin-tunnel tests of model planes, Langley designed and fabricated four different tail configurations for the test airplane. Flight evaluation of each tail's spin characteristics, and how different configurations affect other aspects of plane performance, is a step toward determination of designs that offer minimal susceptibility to stalls and spins. Other investigations in the General Aviation Research and Technology Program address ways to improve overall aerodynamic efficiency; to improve crash survivability; to reduce fuel consumption, noise and exhaust emissions; to develop technology for less complex, lower cost aviation electronics equipment; and to increase the usefulness of aircraft for agricultural spraying applications.

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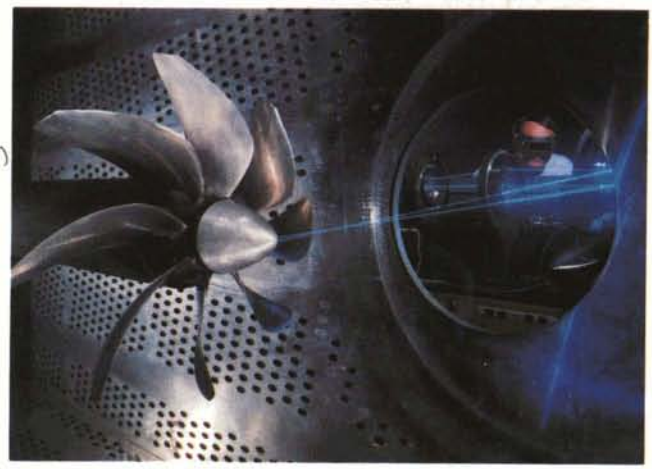


Reborn Propellers

Soaring fuel cost ranks as the biggest problem confronting commercial airplane operators today. In an effort to help combat rising costs, NASA is conducting research on advanced turboprop engines, which offer inherently better fuel economy than jet engines. New multi-bladed, reshaped propellers could enable turboprop aircraft to fly at or near jetliner speeds and altitudes—and provide fuel consumption reductions of 30-40 percent compared with today's transports. The accompanying photo shows a propeller model undergoing wind tunnel test at Lewis Research Center. At right, an engineer outside the tunnel's test section is operating a laser velocimeter system which measures air velocities in the propeller's flow field.

Automated Control Tower

There are almost 200,000 general aviation aircraft operating into some 14,000 U.S. airports, mostly relatively small fields which do not have control towers. To further enhance safety at high-traffic uncontrolled airports, NASA has developed—with the cooperation of the Federal Aviation Administration—an experimental Automated Pilot Advisory System (APAS). The system provides pilots with airport, traffic and weather information in the vicinity of uncontrolled airports, and helps pilots to better meet the "see and be seen" requirement associated with visual flight rule operations. APAS was successfully demonstrated last summer at Manassas Municipal Airport, a busy general aviation field in northern Virginia.

The principal elements of APAS are a radar (below left) for tracking approaching and departing aircraft, a computer system, weather sensors, and a transmitter for computer-generated voice reports to pilots. For the demonstrations, the APAS equipment was housed in a trailer containing an operator's control panel (below right) and instrumentation for checking the system's performance. An operational system concept would be untended and contained in a closet-sized package.

Radar and weather sensor information is fed into the computer system, which translates it into two types of voice advisories for pilots in the area. For advisory reception, user aircraft need no special equipment other than a standard VHF radio tuned to the proper frequency. Every 20 seconds, the computer-generated traffic advisory informs pilots how many aircraft are in the traffic pattern and where they are. Airport advisories broadcast every two minutes provide additional information: they identify the airport, indicate which runway is active, and relate wind speed, direction and other weather data. In the Manassas demonstration, APAS achieved tracking accuracies approaching 100 percent; the system handled 250 to 300 aircraft a week and as many as 10 airplanes at one time.

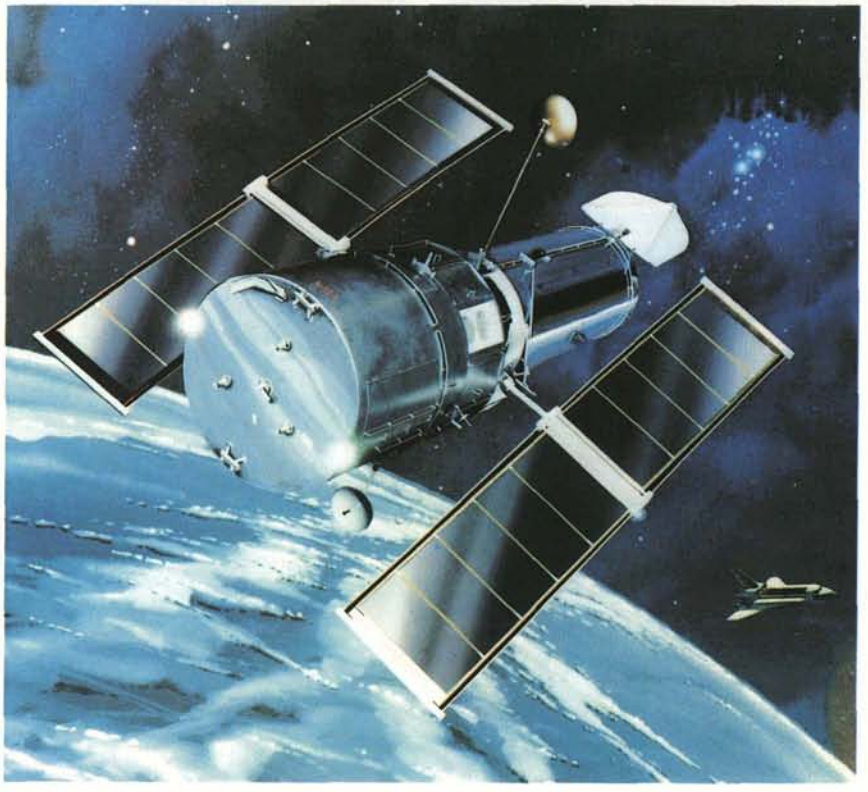
54

55

Exploring the Cosmos

NASA study of the solar system and the space beyond is producing a wealth of knowledge about Earth and its place in the universe

Stars don't really "twinkle." The shimmering effect evident to an earthbound stargazer results from agitated movement of air in Earth's atmosphere, turbulence that impairs the accuracy of astronomical observations. The atmosphere also filters out most of the light and other radiations emanating from distant space, so that a large percentage of the information deducible from such radiations cannot be acquired by ground-based telescopes. Clouds, haze, smog and the light reflected from cities either block or blur the view of space, further limiting the effectiveness of Earth telescopes. For these and other reasons, there is growing excitement among the scientific community about the approaching debut of the Space Telescope, a multipurpose optical system which will operate above the distorting blanket of atmosphere and thus open a new window to the universe.



Since the mid-sixties, NASA has orbited a number of relatively small space-based telescopes which have produced volumes of valuable scientific information. But these predecessor systems bear little comparison with the much larger, much more sophisticated Space Telescope, whose 1985 introduction to service will vastly expand the observable universe.

The largest Earth-based telescopes can see celestial bodies some two billion light years distant. The Space Telescope will be able to see seven times farther—14 billion light years. Its resolution will be 10 times greater and it will provide photographic images of objects 50 times fainter than can now be seen. And it will observe not only visible light, but also infrared and ultraviolet radiation not visible to ground-based instruments.

With this research facility, scientists will literally be able to look back in time and see distant galaxies as they appeared billions of years ago, perhaps at the time of their formation. The Space Telescope may determine whether other stars have planetary systems like our

The Space Telescope will be able to peer seven times farther into space than the largest Earth-based telescopes, provide images 10 times sharper, and detect celestial objects 50 times fainter than can now be seen.

Sun's, and it will allow long-term surface examinations of the other planets in our own solar system, including those not yet visited by spacecraft and only faintly observed from Earth. The system's ability to penetrate hitherto unseen regions of space, and to return sharper imagery than has ever been available, represents an enormous advance in the scientific quest for comprehensive knowledge of the mass, size, shape, origin and evolution of the universe.

The major elements of the 12-ton, 43-foot long Space Telescope are the Optical Telescope Assembly, which includes a 94-inch diameter primary mirror and a smaller secondary mirror; an array of scientific instruments, including two cameras, two spectrographs and a photometer; and a Support Systems Module. The mirrors and associated sensors capture, project and focus incoming light. The scientific instruments analyze and convert the telescopic images to useful scientific data. The Support Systems Module contains devices for precise control of telescope pointing, stabilization and temperature, along with communications, data management and electric power systems. Data acquired by the Space Telescope will be relayed to an Earth-based computer and converted to formats suitable for scientific analysis. Although it is an unmanned spacecraft, the telescope is "manned" in the sense that target pointing, instrument selection and other operations will be controlled by scientists at a new Space Telescope Science Institute, much in the manner that ground-based telescopes are operated.

The Space Telescope project involves the coordinated effort of many government and industry organizations, including NASA, the European Space Agency (ESA) and a number of American and European contractors. Marshall Space Flight Center has overall management responsibility. Goddard Space Flight Center is responsible for the scientific instruments, mission operations and data reduction. Johnson Space Center and Kennedy Space Center will handle Space Shuttle-related aspects of the program—delivery of the telescope to orbit, servicing it periodically in space, and returning it to Earth when major refurbishment is needed. Lockheed Missiles & Space Company is NASA's prime contractor for the Support Systems Module and systems engineering. Perkin-Elmer Corporation is prime contractor for the Optical Telescope Assembly. ESA will supply one of the five scientific instruments—the Faint Object Camera—and the solar array for electrical power generation.

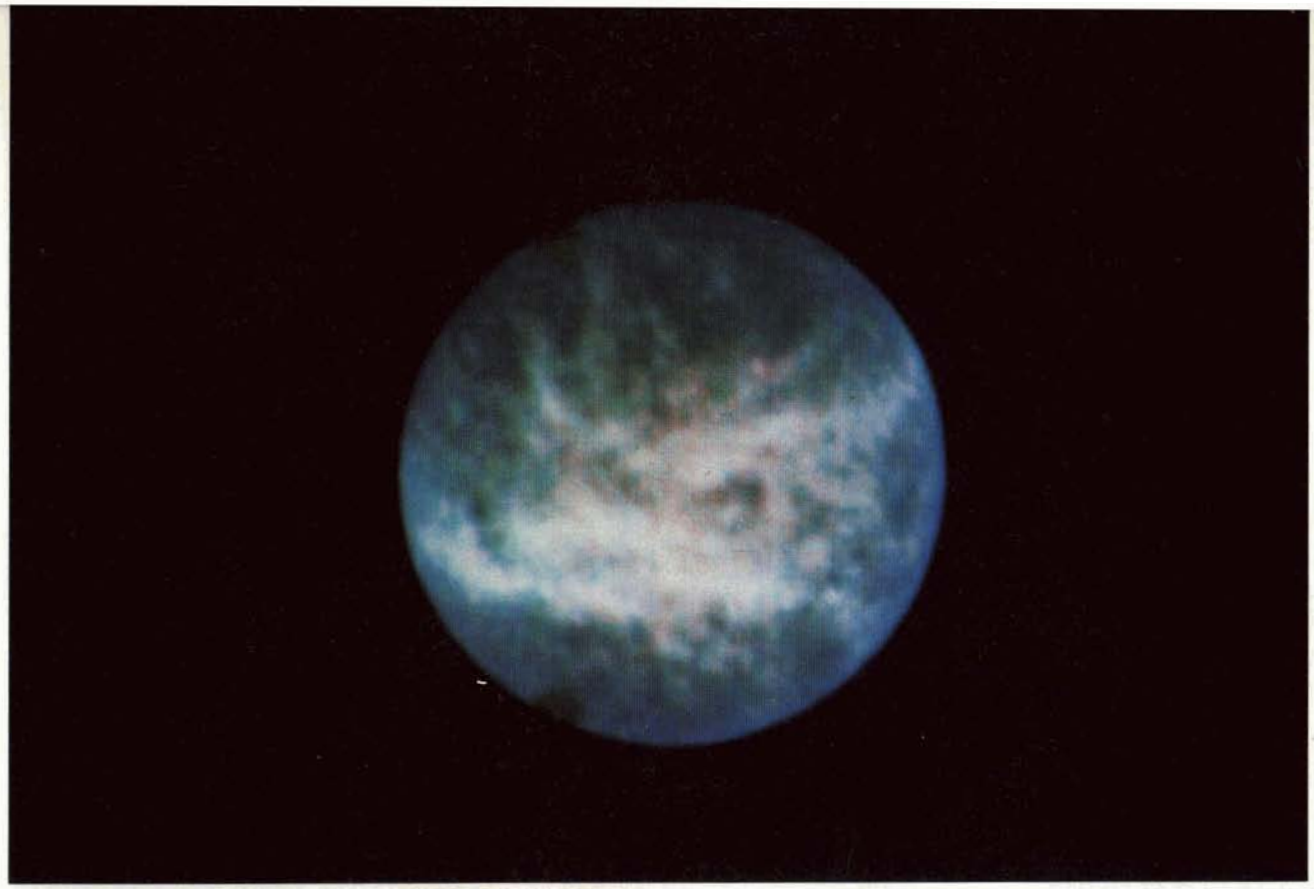
Designed for long lifetime, the Space Telescope will operate at least until the end of the century, its useful life extended by in-space servicing, as depicted in this artist's conception. Space Shuttle Orbiter crews will retrieve the telescope and mount it in the Orbiter's cargo bay for minor repairs or for replacing scientific instruments with more advanced equipment. When necessary, the Orbiter will bring the telescope back to Earth for major refurbishment, then return it to orbit.

The Space Telescope project exemplifies one aspect of NASA's comprehensive, four-pronged space science program—astrophysics research, or study of the distant stars and galaxies. The other areas of activity include planetary research, or investigation of the planets, moons and other phenomena within our solar system; solar terrestrial research, study of the Sun's energy processes and the interactions of solar energy with Earth's environment; and life sciences research, aimed at understanding the origin/distribution of life in the universe and at utilizing the space environment to improve knowledge in medicine and biology.

This comprehensive program is producing a wealth of scientific information. Its essential goal is knowledge of the beginning, the history and the structure of the universe. But there is also an underlying practical aim: learning more about our own planet and the complex forces that control Earth, toward the possibility that greater understanding of nature's forces may bring the ability to manage them for sweeping benefit to mankind.

Planetary Exploration

The 1980 highlight of NASA's planetary exploration program was the November encounter of Saturn by the Voyager 1 spacecraft, which provided the most comprehensive information yet obtained about the ringed planet. Among major discoveries, Voyager 1 found that Saturn's rings (left), earlier thought to number only six, are actually made up of hundreds of individual components termed by scientists "concentric features." Voyager also discovered three new Saturnian moons and reported the presence of bright features resembling Jupiter's "red spot." Below is a false color composite of three separate Voyager images, computer-enhanced to increase the visibility of the large bright features seen above the rings; they are believed to be gigantic storms



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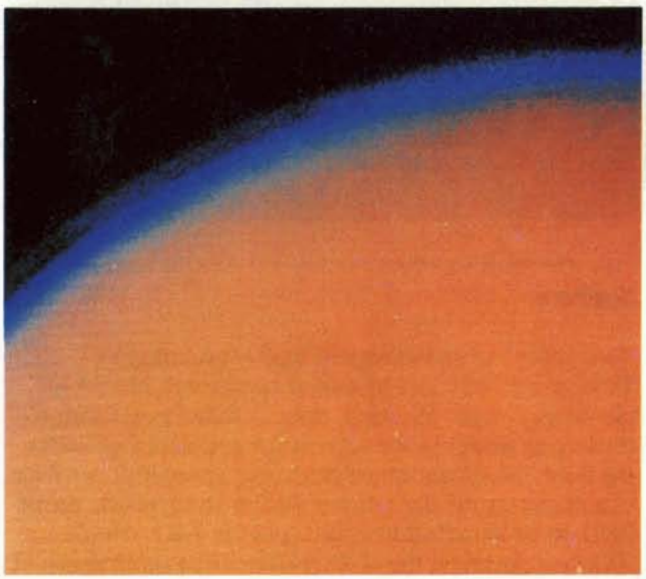


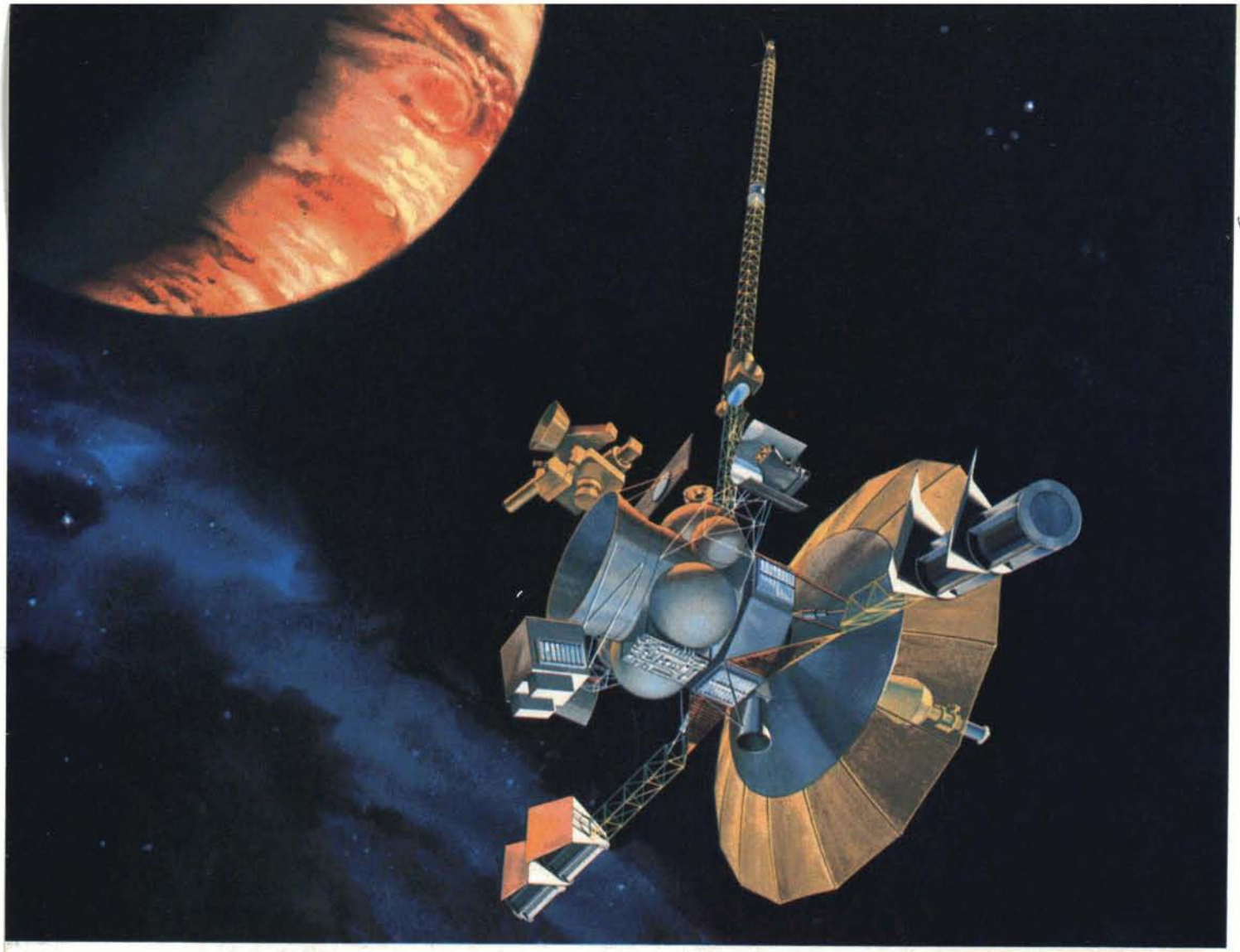
61

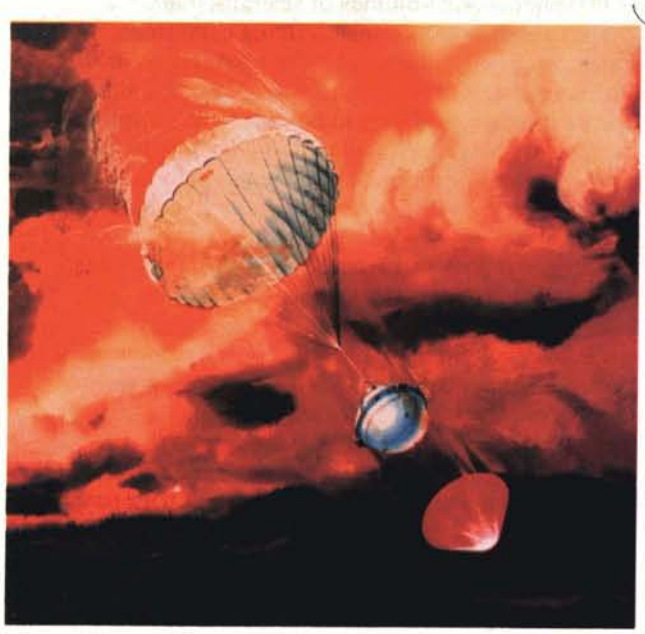
welling up from deep within Saturn's atmosphere. Above is a color portrait of Rhea, third largest of Saturn's 15 moons, reconstructed from three Voyager images taken through violet, blue and orange filters. At left is Saturn's largest moon Titan, the only moon in the solar system which has an appreciable atmosphere; computer enhancement shows in blue the thick haze layer that envelops the planet. In all, Voyager 1 returned some 18,000 photos and volumes of scientific data.

The companion Voyager 2, flying a different trajectory, is en route to a Saturn rendezvous in August of this year. It will provide additional photos and instrument-acquired data to complement the information supplied by Voyager 1 and by Pioneer 11, which conducted the first close-up reconnaissance of Saturn in 1979. Jet Propulsion Laboratory has managerial responsibility for the Voyager project.

In other 1980 planetary research, Pioneer Venus continued to orbit cloud-shrouded Venus, its radar system penetrating the clouds to supply data for computer-generated maps of the planet's never-seen surface. The spacecraft measured the topography of 93 percent of Venus's surface; prior mapping, accomplished by Earth-based radars, had covered less than 25 percent. The Pioneer Venus project is managed by Ames Research Center; Hughes Aircraft Company built the spacecraft.

Elsewhere in the solar system, the sole survivor of four Viking spacecraft is still reporting from Mars—and is expected to do so at least through this decade. Viking Lander 1, which landed on the Red Planet in 1976, is collecting surface photos and weather data, transmitting them about once a week on command from Earth. Jet Propulsion Laboratory is Viking project manager; the Viking spacecraft were built by Martin Marietta Aerospace.





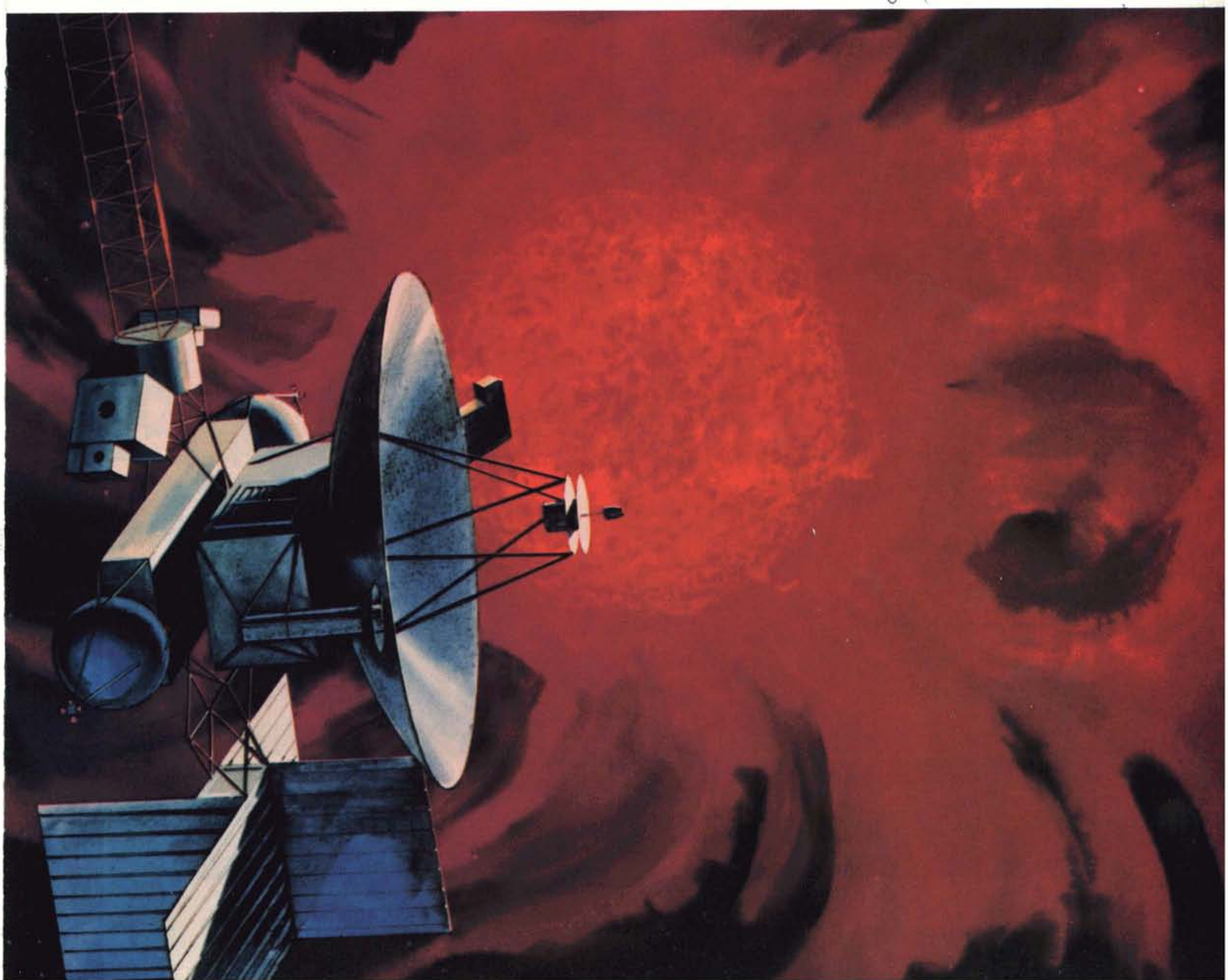
Galileo

To amplify the knowledge of Jupiter provided by Voyagers 1 and 2 and by earlier spacecraft, NASA is planning a longer duration, more detailed examination of the largest planet in the solar system. Called Galileo for the father of astronomical study, the spacecraft consists of a planetary orbiter (above) and an atmospheric probe (left), to be launched toward Jupiter in 1985. After a 30-month journey, the probe will be released to descend into the layers of gas and liquid that comprise Jupiter's atmosphere and relay first-hand data on atmospheric composition and structure. The orbiter will become a man-made moon of Jupiter, circling continuously over a long period to report on Jovian phenomena from many different vantage points. Jet Propulsion Laboratory is overall project manager for Galileo and builder of the orbiter. Ames Research Center is responsible for the atmospheric entry probe, which is being built by Hughes Aircraft Company.

Solar Polar Mission

The ecliptic, which approximates an imaginary extension of the Sun's equator, is the plane in which Earth circles the Sun—and in which all spacecraft have operated. Thus, there is a scientifically important region yet to be explored: interplanetary space above and below the ecliptic, or around the Sun's poles. The first effort to probe this spatial third dimension will begin in the mid-1980s in a joint NASA/ European Space Agency (ESA) project known as the International Solar Polar Mission (ISPM). Hurled out of the ecliptic by the "slingshot" technique, in which the planet Jupiter's immense gravity is utilized as a booster, the ISPM spacecraft will arrive at the Sun three years after launch. Study from this new perspective is expected to amplify and refine earlier-acquired information on such subjects as the Sun's corona, its radiation, magnetic fields and solar winds, hence shed new light on how such solar phenomena impact Earth's environment. Jet Propulsion Laboratory is project manager for NASA.

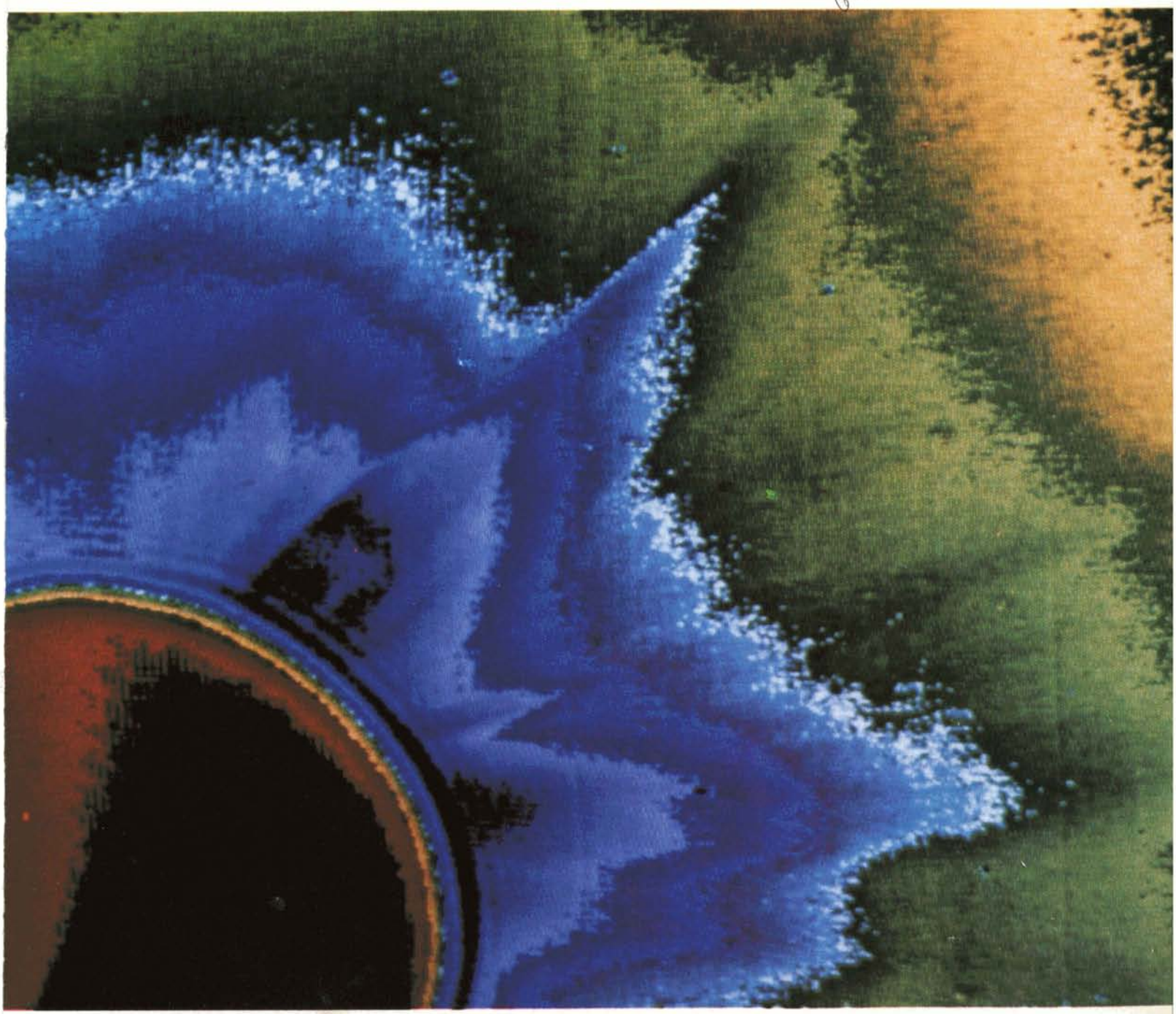
64



Solar Activity Research

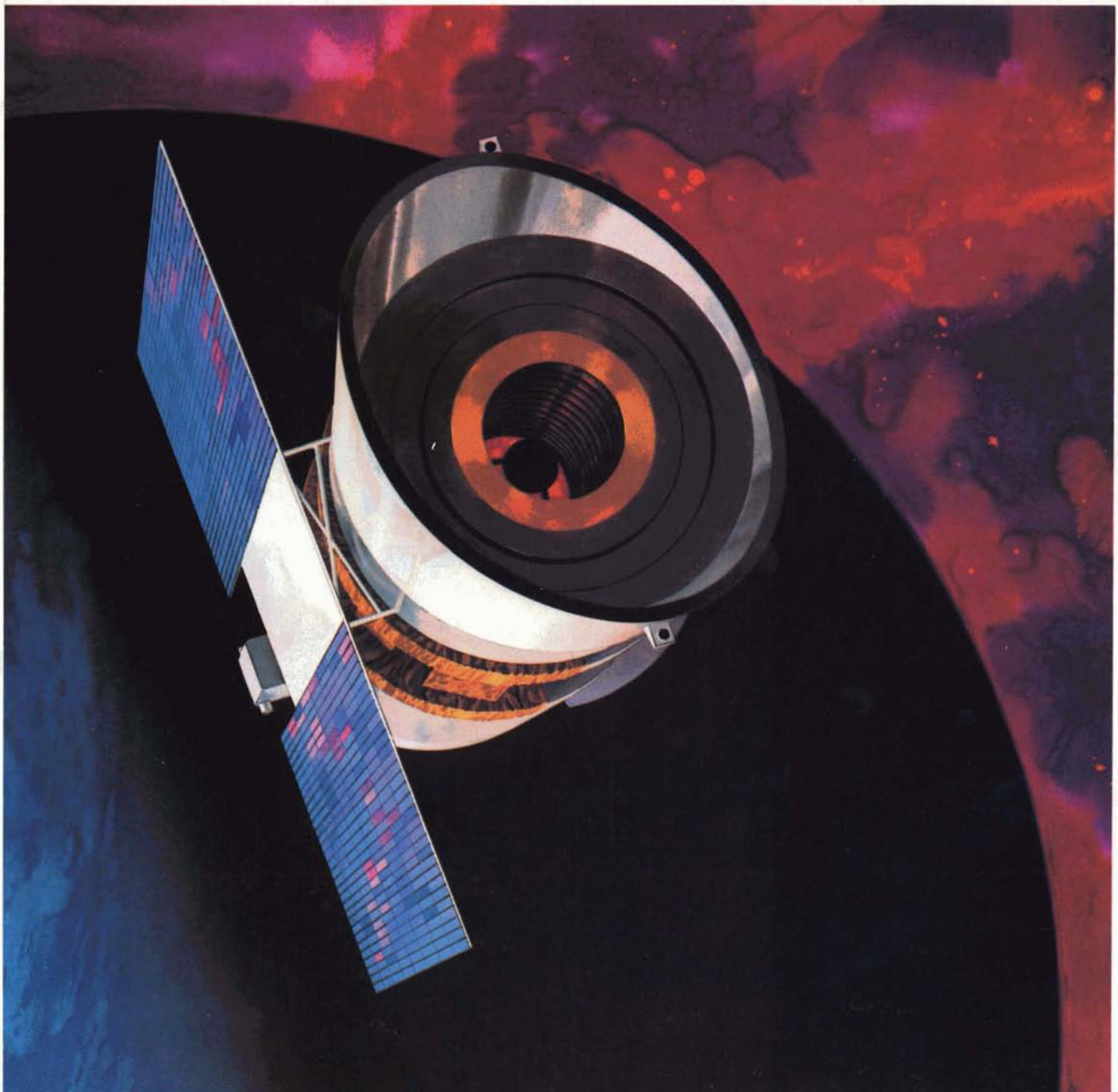
The striking illustrations shown are computer representations of solar activity prepared from data supplied by the Solar Maximum Mission satellite (left) a program managed by Goddard Space Flight Center. Below is a giant solar flare, one of the frequent solar eruptions whose energy release in a few minutes can equal the total energy used by the entire world in many centuries. The false colors in the image on the opposite page indicate different densities—purple the most dense, yellow the least—within the Sun's corona, part of an investigation of coronal disturbances created by solar

flares. From images like these, scientists hope to learn a great deal more about solar energy processes, in particular the causes of solar flares and how they might be predicted. The instruments also made extremely precise long-term measurements of the Sun's radiation intensity, data intended to establish whether changes in total solar heat output affect Earth's climate and weather. Solar Max was launched early last year to take advantage of a peak period in the Sun's activity, which waxes and wanes over an 11-year cycle. The spacecraft contributed to a worldwide effort to study—from ground and space observatories—the Sun/Earth relationship during the International Solar Maximum Year (1979-81).



Infrared Observatory

Infrared radiation emanating from space is partially absorbed by Earth's atmosphere, hence for the most part invisible to ground-based telescopes. NASA has made limited infrared observations from high-altitude aircraft, balloons, sounding rockets and some satellites, but the infrared region remains one of the least explored areas of the electromagnetic spectrum. With the launch of the Infrared Astronomical Satellite (IRAS)—planned for 1982—scientists will have an orbiting facility that will vastly increase the number of celestial infrared sources available for study. The observatory will make possible the first systematic survey of infrared radiation from objects in our own Milky Way galaxy; it will enable study of some stars in death throes and others being born; and it will provide a new chart of the universe, mapping a million infrared sources for future study. The heart of IRAS is a 24-inch aperture infrared telescope with unprecedented sensitivity to infrared radiation, attained by supercooling the instrument. IRAS is a three-nation project; the United States (NASA) provides the telescope and launch services, the Netherlands the satellite and the United Kingdom the control center. Jet Propulsion Laboratory is U.S. project manager and operator of the scientific analysis facility which will produce infrared sky maps and source catalogs. Ames Research Center is manager for the telescope system. Technical participants in the other nations are the Netherlands Agency for Aerospace Research and the U.K.'s Science Research Council.



32

Technology Twice Used

Much of the technology generated by NASA's mainline programs is being reapplied to new products and processes that serve a broad range of public needs and conveniences, providing social and economic benefits of significant order

Spinoff developments highlighted in this section are based on information provided by secondary users of aerospace technology, individuals and manufacturers who acknowledge that aerospace technology contributed wholly or in part to development of the product or process. Publication herein does not therefore constitute NASA endorsement of the product or process nor confirmation of manufacturer's performance claims related to particular spinoff developments described.

A Solution in Search of Problems

Magnetic fluids with unusual properties and far-reaching potential exemplify the scope and value of aerospace spinoff

Chances are you've never heard of ferrofluids; few people have. Yet ferrofluids—magnetic liquids whose unusual properties offer unique advantages in a wide range of applications—represent an emerging technology of such exciting promise it seems likely to spur development of a whole new industry.

Ferrofluids had their genesis in the early days of the U.S. space program. NASA faced a problem: how to feed fuel to the engine of an orbiting spacecraft when the fuel—like everything else in orbit—is weightless. A scientist at Lewis Research Center hit upon the idea of imparting magnetic properties to the fuel by dispersing within it finely ground iron oxide particles; the fuel could then be drawn into the engine by a magnetic source. Ultimately, NASA solved the problem by a different approach and ferrofluid research was shelved for the moment—but the Lewis investigations had planted the seed of a new technology.

Ferrofluids surfaced again in the mid-sixties. At Avco Space Systems Division, scientists were working on another space problem: how to control the temperature of a spacecraft which is very hot on the side facing the Sun and very cold on the other side. Applying their own expertise and drawing on the earlier NASA technology, they came up with a concept wherein a magnetic field would draw ferrofluid through a pipe-ring around the spacecraft, cooling the hot side and warming the cold surface. Once again an alternative solution was found and the operational debut of ferrofluids was delayed.

But not for long. Two of the Avco scientists—Dr. Ronald Moskowitz and Dr. Ronald Rosensweig—realized that ferrofluids offered vast problem-solving potential. Armed with a license for the NASA technology, which served as a departure point for their own further development of ferrofluids, they left Avco in 1969 and formed Ferrofluidics Corporation, Nashua, New Hampshire. Says company president Moskowitz: "We had no products and no customers. We were a company with a solution looking for a problem."

In their first year, they found a problem they could solve, one related to the manufacture of semiconductor "chips" for use in electronic systems. In semiconductor production, aluminum is deposited on silicon wafers within a vacuum chamber. The chamber must be perfectly sealed, since even the most minute exposure to air can destroy the aluminum's conductivity and make the chip useless. Sealing requirements are complicated by the fact that the silicon wafers must be rotated to get even distribution of the aluminum deposit. Thus, the seal must reliably accommodate a rotating shaft into the vacuum

Dr. Ronald Moskowitz, president of Ferrofluidics Corporation, displays some of his company's products. Ferrofluid—magnetic liquid—represents a new technology of exceptional promise in a great variety of practical applications.

chamber. This factor caused frequent chamber leakage induced by wear and breakdown of commonly used seals.

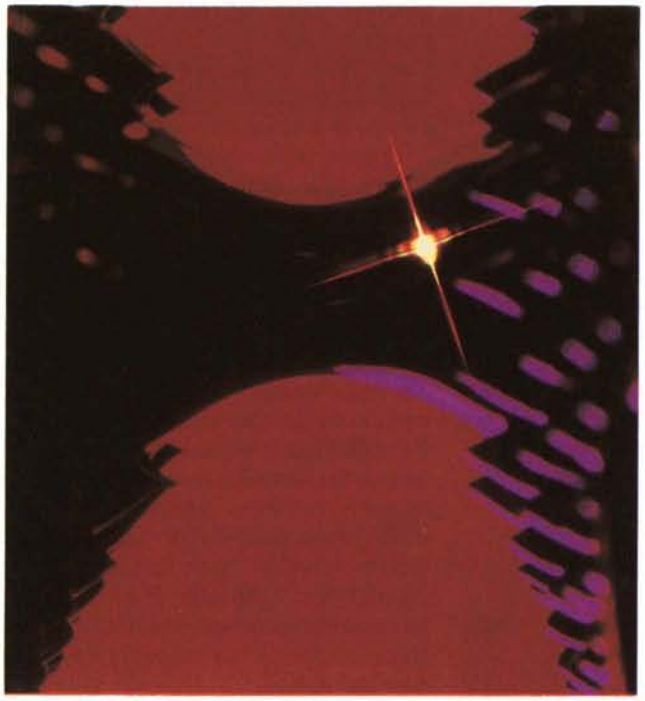
Ferrofluidics' answer was a magnetic seal composed of ferrofluid and a magnetic circuit. The magnetic field confines the ferrofluid in the regions between the stationary elements and the rotary shaft of the seal. The result is a series of liquid barriers that totally bar passage of vapor, mist, gas, lubricants, dirt or other contaminants. The seal is virtually wear-proof and has a lifetime measured in billions of shaft revolutions; it affords substantially reduced maintenance, minimizes "downtime" of production equipment, and significantly reduces the cost of expensive materials once lost through seal failures.

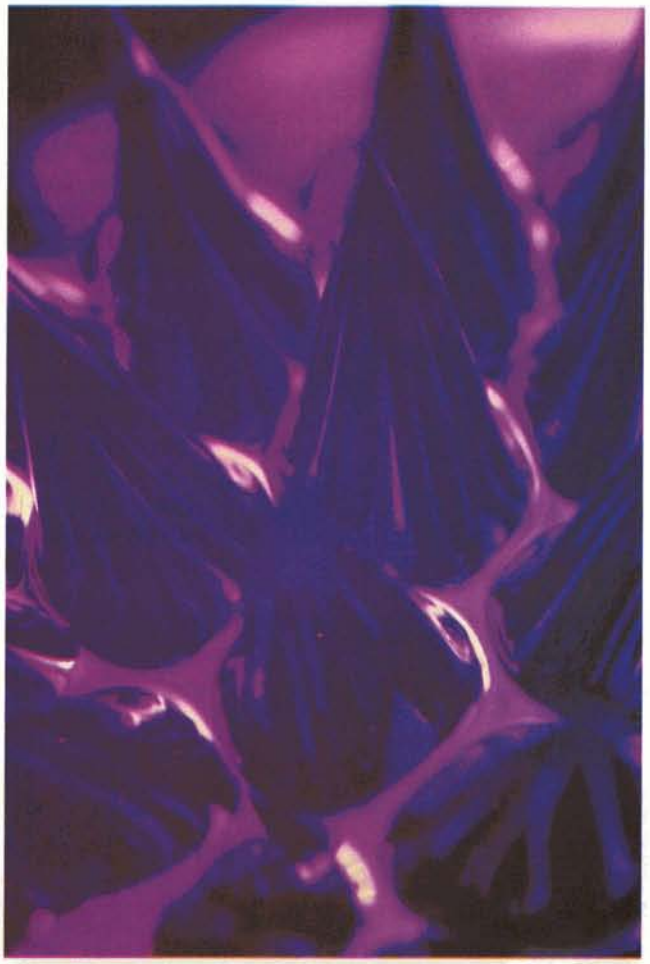
From that start, Ferrofluidics expanded rapidly into many other applications. Among products based on ferrofluid are exclusion seals for computer disc drives and inertia dampers for stepper motors. Ferrofluids are also used as performance-improving, failure-reducing coolants for hi-fi loudspeakers. They are finding growing acceptance in a variety of industrial processes, analytical instrumentation, medical equipment, silicon crystal growing furnaces, plasma processes, fusion research, visual displays and automated machine tools. And that's only the beginning. Dr. Moskowitz sees an "awesome" range of potential applications, from artificial heart pumps to cleaning up oil spills.

From a sales volume of $65,000 in its first year, Ferrofluidics has expanded to annual sales in the multimillions and expects to top the $100 million level within the decade. Now a multidivisional company with European and Japanese subsidiaries, it rapidly outgrew its first plant and is already considering expansion of its new, considerably larger facility. Ferrofluidics is the sole production source for ferrofluids and ferrofluid systems, but there is growing interest in the broad potential of magnetic fluid technology. Says Ronald Moskowitz: "What the NASA technology launched was not just a single company but probably a whole new industry."

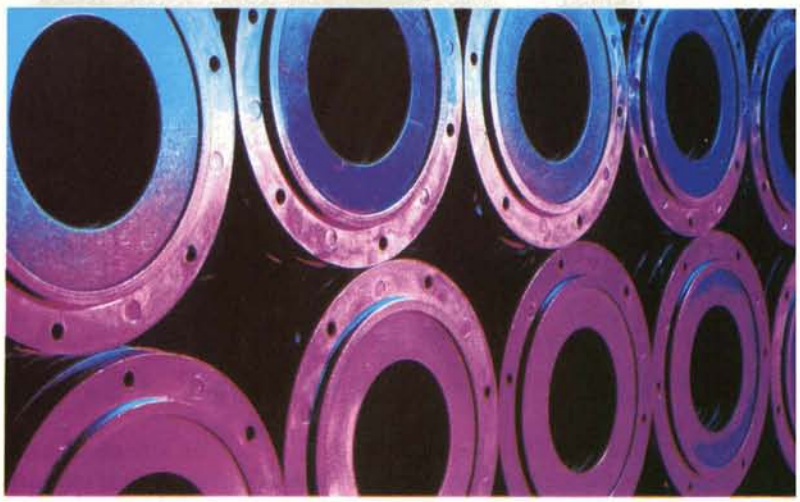
The Ferrofluidics story is an outstanding example of the aerospace spinoff process. It shows the universality of spinoff—how a technology originated to meet aerospace needs can be reapplied in many ways remote from the original application. It also underlines the economic potential of spinoff; as happens frequently, this technology transfer resulted in establishment of an entirely new company, with attendant benefit to the nation's Gross National Product and job creation. Spinoffs whose benefits are valued in the millions of dollars are not unusual. In other cases, spinoffs generate only moderate economic gain, but provide significant public benefits in other ways, ranging from simple conveniences to important developments in medical and industrial technology.

For almost two decades, under its Technology Utilization Program, NASA has been actively engaged in promoting the secondary application of aerospace technology. During that time, thousands of innovations originating in aerospace research have found their way into everyday use. Collectively, these spinoffs represent a substantial return on the aerospace investment in terms of economic gain, improved industrial efficiency and productivity, lifestyle innovations, and solutions to problems of public concern.



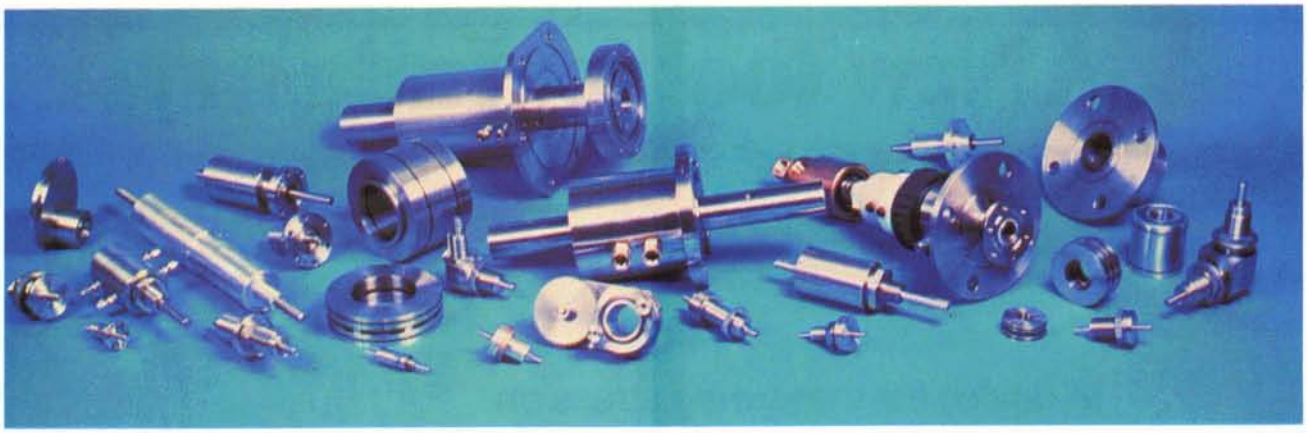


Above, ferrofluid is being pulled in two directions by two magnetic fields. It illustrates how the fluid—which contains freely-suspended submicroscopic iron oxide particles—can be positioned and controlled by a magnetic source. This capability offers many unusual useful applications. The "spiking" phenomenon shown in close-up at right is caused by the energy balance between magnetic forces and surface tension.



This photo illustrates the efficiency of ferrofluid used as a coolant in hi-fi loudspeakers. At left is a conventional speaker. Ferrofluid was injected into the voice coil segment of the speaker at right. The digital readouts show the relative temperatures: 228 degrees Fahrenheit for the conventional unit, only 85 for the speaker containing ferrofluid. Effective cooling of the voice coil substantially increases the loudspeaker system's ability to handle higher power levels and decreases the chance of speaker failure.

A major Ferrofluidics product is an exclusion seal for computer disc drives, which are highly susceptible to contamination; a tiny mote of dust, one-tenth the diameter of a human hair, can damage the disc head and cause loss of the data in the disc's memory. More than a score of computer equipment manufacturers are using Ferrofluidics' seals, which have proved highly effective in protecting stored information.



Among products manufactured by Ferrofluidics Corporation are rotary seals, in which a magnetic circuit controls ferrofluid to form wear-proof liquid barriers that totally block passage of contaminants into sealed vacuum chambers. The company now offers a large line of seals, produced by its Vacuum Technology Division. Ferrofluidics® also has Computer Products and Audio Products Divisions.

®Ferrofluidics is a registered trademark of Ferrofluidics Corporation.

Ferrofluidics recently extended magnetic fluid technology into a new area with the addition to its product line of a system for improving the operation of silicon crystal growing furnaces. Single crystal silicon is the key starting material for solar cells and semiconductor chips. The company's crucible lift system shown lifts and rotates a crucible of molten silicon during the crystal growing process. The highly precise mechanical device permits higher productivity and purer silicon by reducing vibration and contamination.

Ferrofluid offers an effective medium for damping—reducing unwanted vibration—in "stepper" motors, used in such systems as plotters, computer printers, motion picture duplicators, and machine tools. In the photo above is the company's family of Ferrofluidic Inertia Dampers.

A New Tool for Industry

A device for measuring stress on critical bolts exemplifies spinoff aids to industrial efficiency and productivity

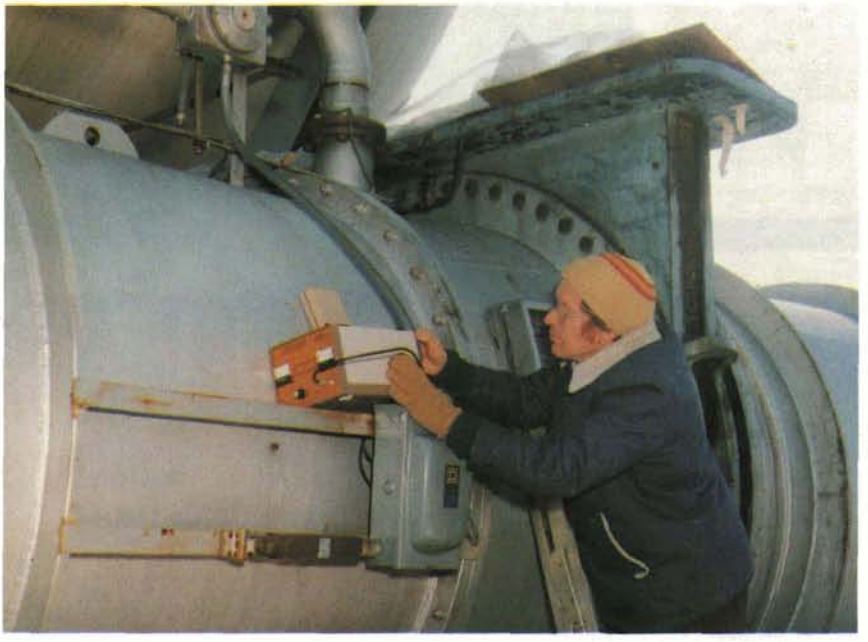
Bolt tightening seems a simple and routine matter. It can, however, be a very important process in cases where the bolt is subjected to severe stresses and strains—for example, in such structures as pressure vessels, bridges or power plants. In these and other instances, exact measurement of bolt stress is critical. Overtightened or undertightened bolts can fail and cause serious accidents or costly equipment breakdowns.

There are a number of methods for measuring bolt stress. Most widely used and least expensive is the torque wrench. But the torque wrench is inherently inaccurate because it does not take into account the variables in friction between nut, bolt and workpiece, which have an influence on bolt stress. At the other end of the spectrum, there are systems which accurately measure bolt stress but require complicated electronics and other equipment which make bolt tensioning an expensive procedure.

For measurement of bolt stress in wind tunnels—where bolted segments must withstand high pressures—Langley Research Center sought a system which would provide extremely precise stress information without the high costs associated with existing accurate systems. The result, after several years of research and development by Langley's Ultrasonic Laboratory, is the ultrasonic P^2L^2 bolt tension monitor, a new industrial tool which is lightweight, portable, extremely accurate because it is not subject to friction error, and cost-competitive with the least expensive of other types of accurate strain monitors.

P^2L^2 is an acronym for technical language—Pulse Phase Locked Loop—which describes to the initiated the essence of the system. In simpler terms, it is an ultrasound system which measures the stress that occurs when a bolt becomes elongated in the process of tightening. The instrument transmits sound waves to the bolt being fastened and receives a return signal indicating changes in bolt stress, changes somewhat analogous to the manner in which a violin string changes tone when it is tightened. Throughout the tightening process, the highly sensitive monitor measures the effective changes in resonance due to elongation of the bolt and changes in the velocity of sound due to strain. The results are

At the Colorado School of Mines Experimental Mine Facility, NASA and the Department of the Interior's Bureau of Mines are testing mine roof bolts with a NASA-developed ultrasonic bolt stress monitor. The instrument monitors the bolt tensioning process and provides increased safety by assuring proper preloading of roof bolts. It also has utility in industrial applications.



An example of the Langley ultrasonic monitor's utility is shown in this photo of a large valve assembly where a flange is being jacked into place. Measurement of the strain differences among the bolts provides information for exact alignment of the flange.

translated into a digital reading of the real stress on the bolt, a guide to proper fastening.

One version of the monitor is now entering industrial service and Langley has developed a new version for a special, potentially important application: checking bolt stress in the roofs of mine tunnels, where mammoth bolts several feet long extend far into solid rock. In a cooperative program with the Bureau of Mines, Langley is conducting tests to see if the device offers an improved way of assuring mine safety by determining whether a bolt is truly stressed. Langley and the Bureau of Mines are planning a further step: modifying the monitor to measure stress of the rock surrounding a mine tunnel. Rock stress varies from mine to mine and it may change over time due to such influences as shifting rock or mining techniques; detection of stress changes could serve as a hazard warning. If direct rock stress measurement proves feasible, it could provide broad benefit to mining, highway tunnel construction and related activities, such as earthquake prediction.

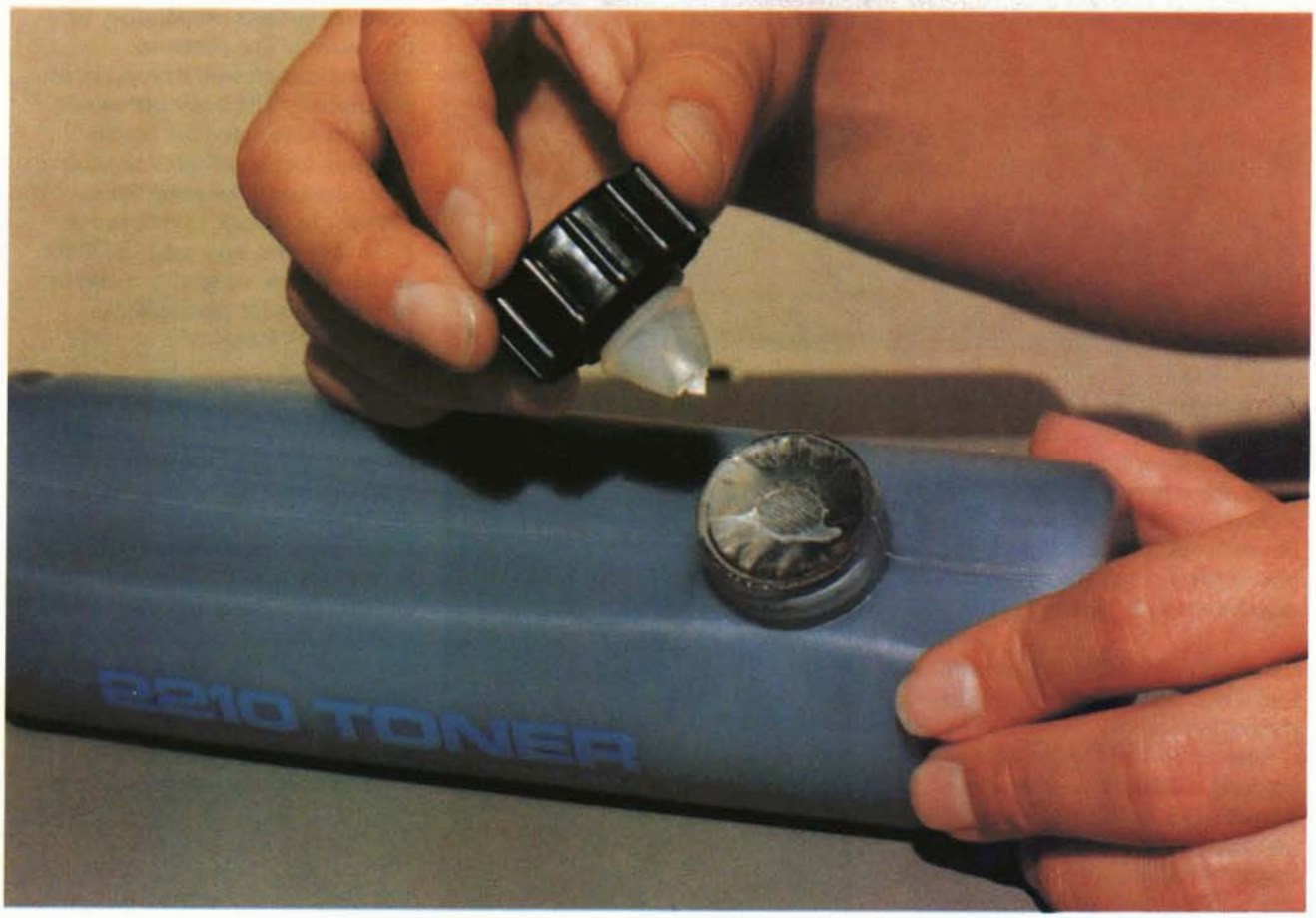
Langley's P^2L^2 bolt tension monitor has aroused considerable interest in industrial circles. NASA has patented the instrument and a number of companies have been granted licenses for its commercial manufacture; some are already producing it and others are conducting tests preparatory to production. The potential applications go well beyond bolt monitoring. The basic ultrasonic systems developed during the program can be adapted to such other uses as measuring stress changes in metals, investigating lubricants and hydraulic fluids for contaminants, or testing blood or other liquids for particulates, bubbles or clots.

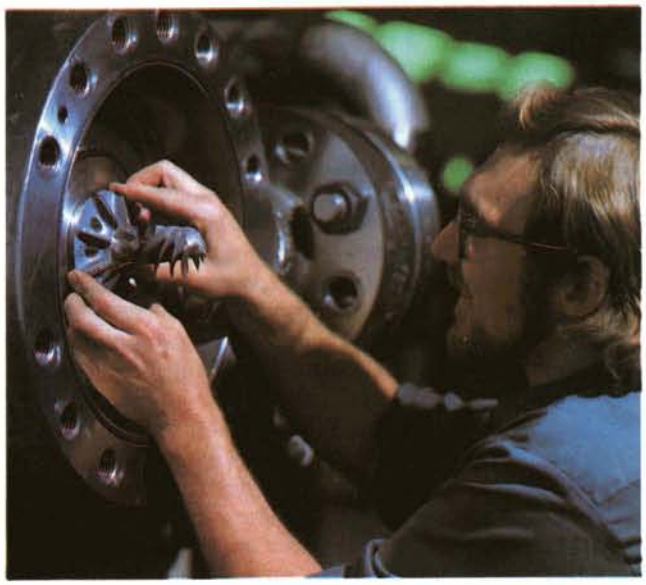
In turbine engine construction, rotor fan blades must be fastened with precise tolerance between blade and housing, not only at installation but during engine operation—when the loads on the blades change due to high temperature and high rotational speed. Here the ultrasonic strain monitor, attached to a blade/rotor assembly, is measuring the preload on a fastener with a degree of accuracy not attainable by conventional torque systems, thereby assuring precise tolerance.

Copying Machine Improvement

NASA-supplied technical information helped a New England office equipment manufacturer solve a design problem and realize substantial savings in the process. Nashua Corporation, Nashua, New Hampshire manufactures, among other products, the recently introduced Model 2210 copying machine (below). The company's problem involved the valve on the liquid toner cartridge, shown being inserted in the 2210 copier (below right). Under extreme conditions of time and temperature, the valve bushing would secrete an effluent into the toner well; this caused a lightening of copies to the point where they were unusable.

Looking for a plastic valve bushing material that could be produced by a low-cost injection molding process, Nashua Corporation requested assistance from the New England Research Application Center (NERAC), one of seven NASA Industrial Applications Centers. NERAC conducted a computer search of the NASA data base and was able to supply several technical reports on the properties and performance of candidate materials. This information proved to be the key to company development of a urethane valve bushing (bottom) which solved the problem and afforded a dramatic reduction in unit cost. Worldwide valve use is about a million a year and savings are estimated at $250,000 annually.





Pump Design

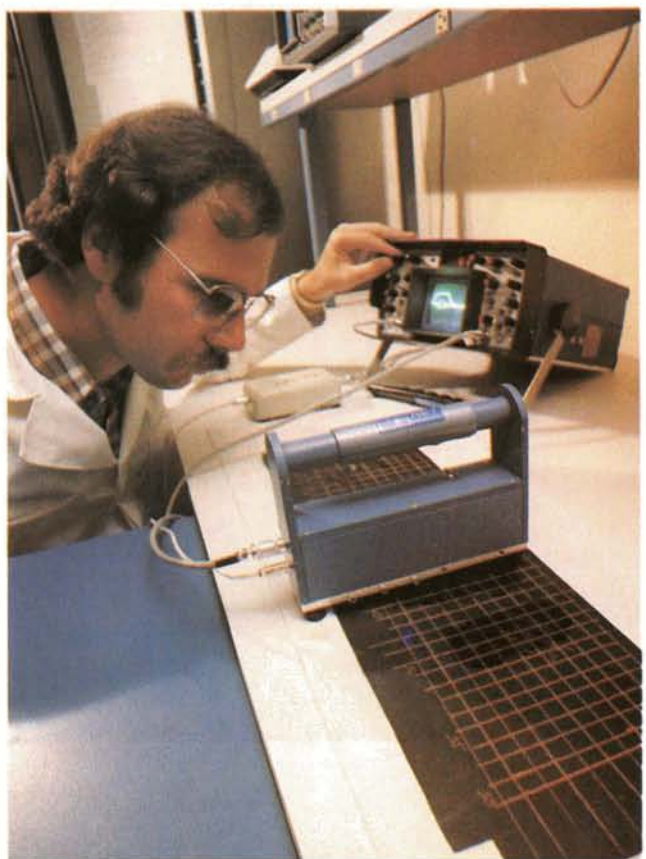
The above photo shows a technician of Sundstrand Corporation's Fluid Handling Division, Arvada, Colorado installing a titanium impeller on a Sundstrand centrifugal pump. NASA technological information proved useful in improving the company's line of pumps and compressors employed by petroleum and chemical processing firms.

Titanium is frequently used in high-speed pump and compressor components, particularly in parts subjected to corrosive or erosive fluids. A Sundstrand engineer, interested in acquiring more information on the corrosion resistance and strength characteristics of titanium, learned of a NASA handbook on a general purpose titanium alloy; typically used in aircraft and missile structures, the alloy is highly resistant to the corroding effects of salt water, many acids, alkalis and other chemicals. Developed by Marshall Space Flight Center, the handbook provides comprehensive detail on the properties of the alloy, including corrosion and other environmental effects, together with information on fabrication and joining techniques. Sundstrand obtained the handbook and used it in design calculation for casting titanium impellers. The company reports that NASA information contributed substantially to improved impeller design.

Testing Composites

Growing aerospace use of composite materials prompted Lewis Research Center to look for better ways of testing composites for strength characteristics. Ultrasonics, a proven method of testing metals, was considered unsuitable for testing composites; it might show the structure free of defects when in fact the structure's strength was inadequate due to faulty fabrication or deterioration over time. Seeking a nondestructive method that would detect flaws and also evaluate a composite material's strength and endurance, Lewis came up with a system that combines a proven technique—ultrasonics—with a relatively new technique known as acoustic emission testing. In this system, ultrasonic "stress waves" are injected into a composite structure. As the stress waves propagate through the material, their character is affected by the same factors that influence the material's strength properties. Thus, analysis of how the stress wave is affected provides a basis for predicting composite material strength and response to stresses.

Shown being used to examine a composite sample (below), the Lewis-developed Acoustic Emission/ Ultrasonic Test Instrument is produced by Acoustic Emission Technology Corporation, Sacramento, California. Designated the Model 206AU, the lightweight, portable system has three main sections. The "pulser" section injects ultrasonic waves into the material under test. A receiver picks up the simulated stress waves as they pass through the material and relays the signals to the acoustic emission section, where they are electronically analyzed. In the display section, flaw and strength assessment information is presented simultaneously in both graphic and digital form.



Heat Pipe Technology

In the early days of space flight, NASA sought to solve a problem stemming from the fact that Sun-facing surfaces of a non-rotating satellite become excessively hot while surfaces not exposed to the Sun become very cold. Since this temperature differential could cause failure of electronic and other spacecraft systems, NASA contracted with Los Alamos Scientific Laboratory (LASL) for development of a heat distribution system for non-rotating satellites.

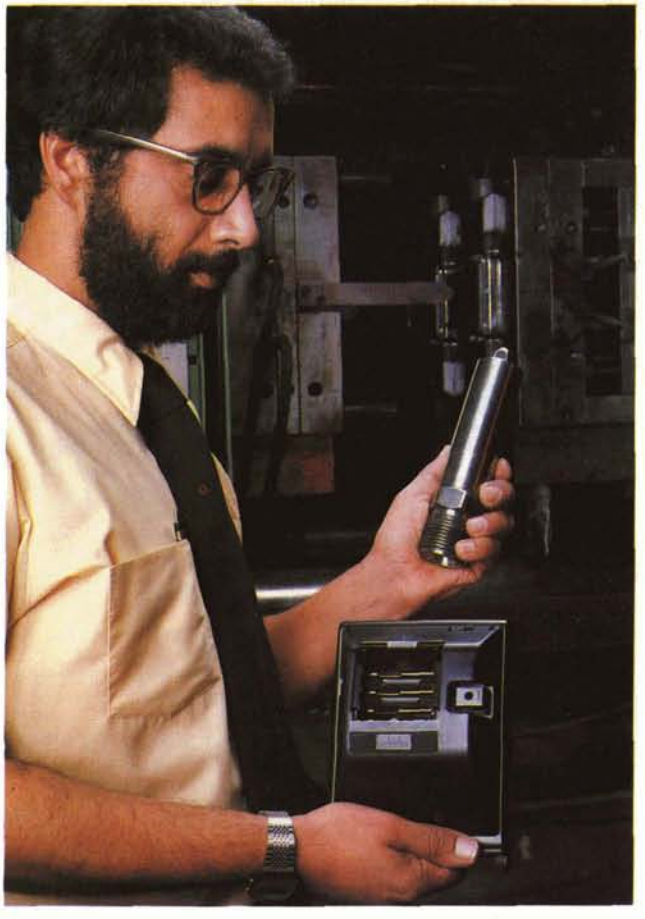
LASL's answer was the heat pipe, a sealed chamber whose walls are lined with a "wick," a thin capillary network containing a working fluid in liquid form. When heat is applied to a portion of the pipe, the working fluid evaporates and carries the heat away from the heated pipe segment. As the vapor comes in contact with cooler sections of the pipe, it condenses, releasing heat, warming the hitherto cool pipe segments and restoring the vapor to liquid form. The liquid is then returned through the wick to the heat source to be vaporized again, providing a continuous heat transfer mechanism.

James M. Stewart, Greenville, South Carolina, an independent consultant to the plastics industry, obtained detailed information on heat pipes through NASA's Technology Applications Center at the University of New Mexico. Stewart incorporated the NASA/LASL technology, among others, in his own development of patented "heat tubes" that improve temperature control in plastics manufacturing equipment.

In 1978, when Kona Corporation, Gloucester, Massachusetts was formed to manufacture plastic extrusion and molding equipment, the company obtained a license from Stewart for the use of heat tubes. This technology, Kona Corporation states, offers an answer to a problem common in plastics manufacture: high maintenance costs and excessive molding machine downtime due to frequent burnout of heater bands normally used to distribute heat to molding nozzles and other equipment. The Kona Nozzle® for heaterless injection molding gets heat for its operation from an external source and has no internal heating bands, reducing machine maintenance and also eliminating electrical hazards associated with heater bands.

Eastman Kodak® Company, Rochester, New York uses Kona Nozzles to maintain uniform heating of plastics in molding parts for cameras; at lower left, a company employee is holding the nozzle in his left hand and the molded back of an instant camera in his right. The nozzles are also used by Bic Pen Corporation, Milford, Connecticut for molding pens and lighters such as those shown below. Among other products molded by Kona Nozzles are Polaroid cameras, Tupperware plastic kitchenware, Ford Motor Company auto components, RCA television cabinets, and Western Electric telephones and components.

® Kona Nozzle is a registered trademark of Kona Corporation.
® Kodak is a registered trademark of Eastman Kodak Company.

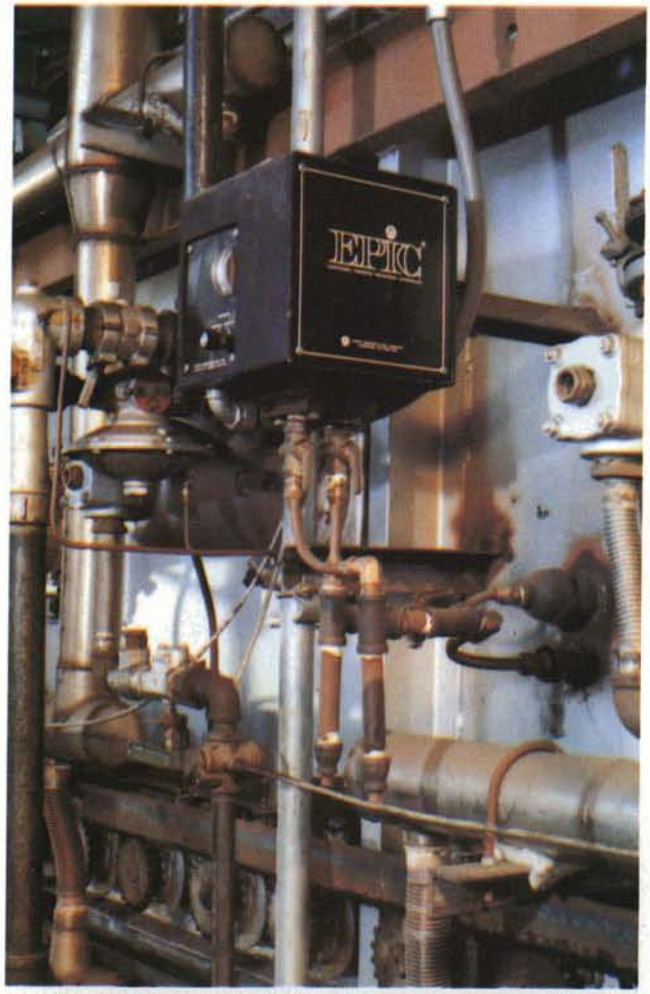


Laser Balancing

In production or overhaul of turbine machinery—aircraft jet engines, for example—a key factor in assuring proper turbine performance is precise balancing of the rotor, a disc-like part which revolves around a shaft at extremely high speeds. By conventional methods, rotor balancing is a tedious and time-consuming task. It is a manual operation in which a rotor is spin-tested, then stopped to remove or add material for balance, spun again and rechecked in multiple runs until proper balance is attained. Rotor metal is removed by hand drilling or grinding; material is added in the form of prefabricated correction weights.

Looking for a more efficient, continuous method of rotor balancing, Lewis Research Center and Mechanical Technology Incorporated, Latham, New York jointly developed a fully-automatic laser machining process that offers multiple advantages. It allows more precise balancing, removes metal faster, eliminates excess metal removal and other operator-induced inaccuracies, and provides significant reduction in balancing time, hence lower manufacturing costs.

Shown in operation in the accompanying photo, the system employs a cutting laser to remove metal at rates precisely controlled by a computer. In operation, the rotor is mounted on a balancing fixture and rotated. While the rotor is spinning, the computer detects the degree of imbalance, calculates the required corrections and feeds this information to a control unit. The controller positions the cutting laser so that it is aimed at the exact spot on the rotor where material is to be removed. The laser fires short-duration high-energy pulses, removing the required amount of material from each plane of the rotor until the computer determines that the programmed balancing tolerances have been satisfactorily achieved.



Pressure Controller

The EPIC® black box at left is an Electronic Pressure Indicating Controller produced by North American Manufacturing Company, Cleveland, Ohio. A high-sensitivity device for improving combustion efficiency in industrial furnaces, it interprets a signal from a pressure transducer on a furnace and regulates furnace pressure accordingly. Shown below in use at Pittsburgh Commercial Heat Treat Company, Pittsburgh, Pennsylvania, the EPIC controller is produced in several versions, each of which operates in a different pressure range. The unit incorporates a diode-quad bridge circuit developed by Ames Research Center for use with pressure-sensitive transducers, liquid level measuring devices and other sensors.

A North American Manufacturing Company engineer engaged in designing furnace controls learned of the bridge circuit through *Tech Briefs,* a NASA quarterly publication which describes innovative technology available for transfer. He requested and received from Ames detailed technical information; the company was later granted a NASA license for use of the technology. The diode-quad bridge circuit is part of a larger EPIC circuit that controls furnace pressure to a user-adjusted level to provide maximum furnace efficiency. A company official says that the controller can provide savings of from five to 25 percent of an industrial user's annual furnace fuel bill. More than 1,000 of the devices have been sold and the market continues to expand as fuel prices climb.

® EPIC is a registered trademark of North American Manufacturing Company.

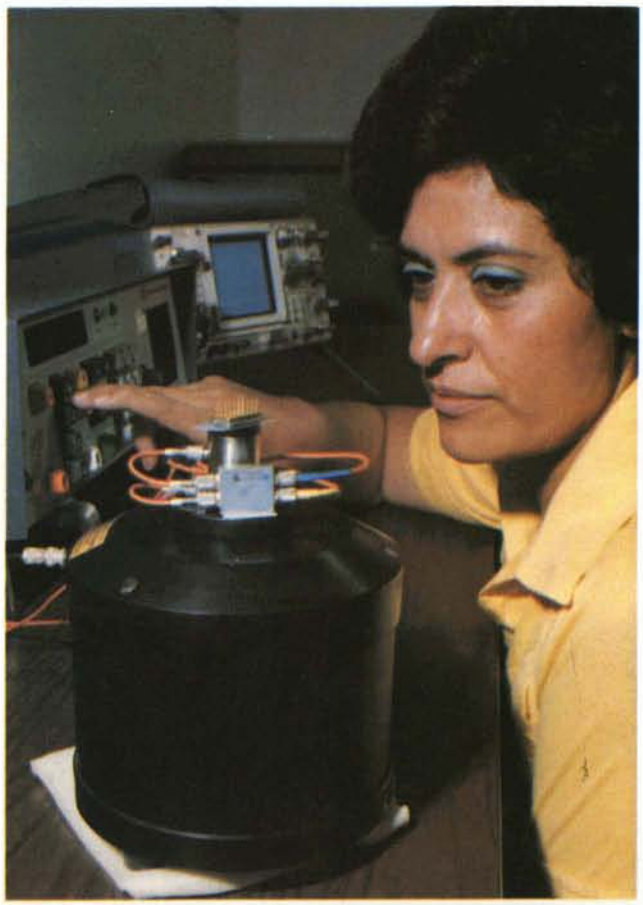
Loose Particle Detection

PIND is an acronym for Particle Impact Noise Detection, a means of finding tiny, loose, conductive particles, introduced during fabrication of integrated circuits, which sometimes cause system failures. The instrument pictured is one of two types of automated systems used for PIND testing. Produced by Dunegan/Endevco, San Juan Capistrano, California, it determines the presence of loose particles by detecting the sound of an impacting particle. PIND testing equipment is also produced by B&W Engineering Services, Costa Mesa, California.

The device undergoing test is attached to an acoustic transducer mounted on a shaker. The test equipment induces a series of shocks and vibrations to free particles clinging to the interior of the device. When a freed particle strikes some interior portion of the electronic package, the sound energy of the impact—which is in the ultrasonic range and inaudible to the human ear—is detected by the transducer. The resulting signal is used to provide both audio and visual monitoring of the test. If the signal exceeds a certain threshold, a light on a panel indicates that the device being tested has failed.

Goddard Space Flight Center made an important contribution to the technology with a study, completed last year, intended to determine PIND effectiveness. Previous attempts to quantify PIND testing had involved examination of failed parts to confirm the presence of loose particles—but parts which passed the PIND test were not examined for the absence of particles because that would have required destruction of costly items. The Goddard study was designed to determine true PIND effectiveness by foreknowledge of which parts contained particles—and therefore should fail the PIND test—and of other parts which did not contain particles, and therefore should pass. Goddard sent electronic packages to some 70 organizations—semiconductor manufacturers, users and test laboratories—for PIND testing, having beforehand introduced loose materials in 80 percent of the packages.

Analysis of the test data indicated that an average PIND detection capability of about 45 percent can be



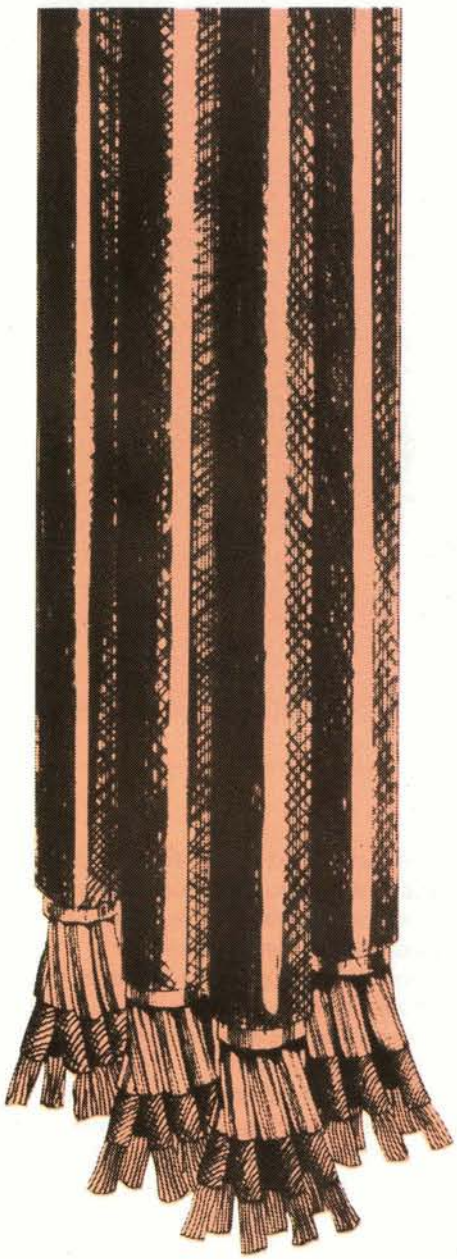
expected. There are many variables which can reduce or increase that figure significantly—operator motivation and training, the test equipment and its condition, the package style of the device under test, repeated testing of the parts, the size of the contaminating particle and operating test conditions, for example, whether the test site is noisy or quiet. Although the 45 percent figure seems low, Goddard experts feel that PIND is the best available test method and accurate knowledge of its detection capability is necessary to determine PIND's cost-effectiveness and to judge the merit of employing it in systems of different criticalities.

Technology for Transportation Safety

Fire-resistant materials for passenger-carrying vehicles lead a selection of spinoffs in public safety

Long concerned about fire and smoke hazards, the public transportation industry is constantly seeking improved passenger safety through development of materials more resistant to fire for use in vehicle interiors. Two new materials that originated in aerospace research represent steps in that direction.

In prototype service on cars of the Bay Area Rapid Transit system is a major development in public transportation safety, a new polyimide foam material with greater flame resistance than other materials currently employed in transit car interiors.



NASA technology was incorporated in development of a safety enhancing insulating material for Lo-Smoke cable assemblies used in rapid transit systems.

For several years, Johnson Space Center (JSC) has been conducting research on advanced flame-resistant materials toward minimizing fire hazard in the Space Shuttle and other flight vehicles. From that program has emerged a polyimide foam material that resists ignition better than any materials earlier used. It is applicable not only to flight vehicles, but also to surface transportation systems such as rapid transit cars, trains, buses and ships.

Known commercially as Solimide®, the material was developed under JSC contract by Solar Turbines International, San Diego, California, a subsidiary of International Harvester. The polyimide foam's broad safety potential stems from the fact that it does not ignite when exposed to open flames, it only chars and decomposes. Since the material does not "outgas" until it begins to char, it is also safer than current materials with respect to toxic fume generation. The polyimide can be made in two forms: a "resilient" foam for such soft components as seat cushions, and a rigid foam for door, wall, floor and ceiling panels.

A polyimide foam is in prototype service on the San Francisco/ Oakland Bay Area Rapid Transit (BART) system whose officials were looking for a better interior material after a 1979 fire that caused one fatality. NASA's SRI International Technology Application Team, Menlo Park, California arranged for engineers from BART and the California Public Utilities Commission to witness full-scale polyimide fire tests at Johnson Space Center. SRI later provided samples of the material for independent BART testing. As a result of those tests, BART is using rigid polyimide foam as the core of car-end doors.

Resilient polyimide foam is being suggested as a replacement for polyurethane in airliner seat cushions, which represent the largest amount of flammable material in commercial transport interiors. In addition to reducing in-flight fire risks, polyimide offers bonus advantages. In a ground emergency, the material's flame resistance could lengthen—from two minutes to five minutes—the time needed for passenger evacuation. And since the foam is about 50 percent lighter than current materials, it could also help reduce airline fuel consumption by trimming aircraft weight. In a cooperative NASA/Federal Aviation Administration (FAA) program, polyimide seats will be evaluated in test fires at the FAA's Technical Center, Atlantic City, New Jersey.

NASA technology also contributed to development of a new type of smokeless wire and cable insulation. Because of several subway fires in which burning wire and cable insulation propagated the flames and created much smoke, the rapid transit industry placed high priority on a search for an affordable smokeless insulation material. To see if NASA research offered a solution, the SRI Technology Application Team circulated a statement describing the problem among NASA centers.

Jet Propulsion Laboratory (JPL) responded with a possible approach borrowed from solid rocket propellant technology: a technique known as bimodal distribution in which a binder—insulating material—is loaded with inorganic filler, thereby reducing the portion of the material that will burn and smoke. After extensive research, JPL produced a candidate formulation which minimizes smoke and flammability yet provides requisite mechanical strength.

Seeking to arrange commercialization of this technology, the SRI team interested Boston Insulated Wire & Cable (BIW) Company, Boston, Massachusetts. BIW expanded the bimodal distribution concept to include a number of additional formulations. The JPL work served as a departure point for BIW's development of an advanced wire and cable jacketing material with superior flame resistance and smoke retardation characteristics. The material is incorporated in the company's line of Lo-Smoke® cable assemblies, which are being supplied to mass transit systems in the United States and abroad.

® Solimide is a registered trademark of Solar Turbines International.
® Lo-Smoke is a registered trademark of Boston Insulated Wire & Cable Company.

Firefighting Module

A highly versatile NASA-developed mobile firefighting module made its commercial service debut last year at Dow Chemical U.S.A.'s Texas Division, Freeport, Texas. The Dow module—called Firefly II and manufactured by Aviation Power Supply, Inc., Burbank, California—is mounted on a trailer pulled by a pickup truck (above). The trailer unit has two three-inch water "cannons" and the pickup carries a six-inch cannon, compared with the standard 2½-inch hoses used by most fire departments. Completely self-contained, the module pumps 3,000 gallons of water a minute from hydrants or open bodies of water. It can deliver its fire-quenching stream as far as 400 feet (left), or it can be employed in a high-loft mode to reach the tops of tall refinery towers (below left). The photos were taken during a 1980 Firefly demonstration at the Dow facility.

For suppressing ship or waterfront fires at the Freeport marine terminal, the Firefly trailer can be backed onto Dow's specially-built barge fireboat (upper right). Firefly also serves as a backup to the Freeport facility's underground fire main system; should the basic system become inoperable during an emergency, the mobile module could draw water from a pond or canal and feed it to the company's standard fire trucks.

The compact Firefly II weighs only 2,500 pounds when fully fueled but it contains everything needed to fight a fire. The key component is a specially-designed two-stage pump produced for Aviation Power Supply by the Ingersoll-Rand Pump Group. Power for the pump is generated by a gas turbine engine—a derivative of a helicopter engine—built by Detroit Diesel Allison Division of General Motors Corporation. The module also includes an electronic engine/pump controller,

multiple hose connections, up to 1,500 feet of hose, and fuel for four hours operation.

Firefly II is a commercial offshoot of a NASA/Coast Guard program involving development of a lightweight, helicopter-transportable firefighting module for quick response in combating shipboard or harbor fires. In directing the development effort, Marshall Space Flight Center drew upon its aerospace experience in high-capacity rocket engine pumps, lightweight materials, and compact packaging. The pump was developed under Marshall contract by Northern Research and Engineering, Woburn, Massachusetts, a division of Ingersoll-Rand. The Firefly I that emerged from the development program is being tested in demonstrations and regular operational use at St. Louis, Missouri (below) in a program jointly sponsored by NASA, the Maritime Administration and the Coast Guard. Aim of the program is to evaluate the module's effectiveness and cost-reduction potential as an emergency-use system aboard commercial tugboats operating as auxiliary fireboats. The city of Miami is also evaluating the Firefly as a waterborne fire protection system.

Lightning Current Detector

In this photo of a Kennedy Space Center (KSC) launch complex, the device in the foreground is a Lightning Current Detector (LCD) developed by KSC to monitor the magnitude of lightning strikes. The information it supplies is useful in evaluating lightning protection designs for such systems as telephone cables, radio broadcast towers, power transmission equipment and oil well towers.

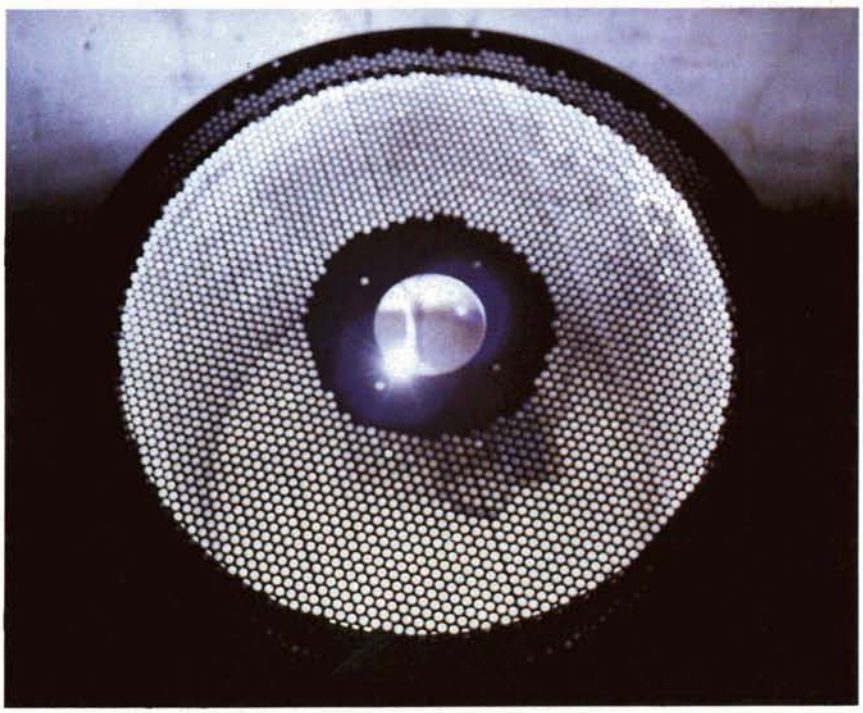
Intended to overcome disadvantages in earlier methods of lightning current measurement, the LCD is a simple, passive device requiring no external equipment, power or human attention. Its prime component is a length of magnetic tape on which a reference signal has been prerecorded. The tape is housed within a plastic tube mounted perpendicularly to an exposed conductor—for example, a guy wire. When lightning strikes the wire, the current creates a magnetic field that erases part of the prerecorded signal on the tape. By playing back the tape and timing the erased portion with the assistance of a special meter, it is possible to compute the peak lightning current.

For further development of the detector, the Department of Energy contracted with the University of Florida for a study in which 150 LCDs were tested along power lines to determine lightning effect on power distribution systems; KSC assisted the university's Electrical Engineering Department in modifying the LCD for the project. NASA has also awarded a contract to Lightning Technologies, Inc., Pittsfield, Massachusetts to improve methods for using the devices in various applications.

Perforated Materials

An example of the technical assistance provided industry and government clients by NASA's Industrial Applications Centers is a research task performed for National Perforating Corporation (NPC), Clinton, Massachusetts. NPC, a member of the Industrial Perforators Association (IPA), is a supplier of perforated metals, plastics and other materials exemplified by the accompanying photos. At right is a metal sheet coming off the perforating press, the first step in the manufacturing process. Below is a perforated screen used for the processing of pulp in paper manufacturing. In producing screens, walkways and other products for all industries, the company and the IPA sought to determine the safe loading of such perforated metal products. Unable to find the needed information, the association was considering commissioning a study, which would have entailed considerable expense.

Before going ahead with the study, the company requested assistance from NASA's New England Research Application Center (NERAC) at the University of Connecticut. NERAC conducted an extensive computer search and supplied NPC an informational package, including identification of a firm which had already accomplished substantial study, test and evaluation of the strengths of perforated materials. NPC found that the information sought was available from that firm—at a fraction of what a new study would have cost, with a bonus in time saving. Assistance provided by NERAC will be shared by the association's 14 other member companies. The NERAC study also provided NPC and the IPA with many other sources of information about perforated materials in such areas as flow of gases and liquids over and through perforated plates, acoustical applications and filtration.



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Yacht Race Monitoring

Above, yachtsman Philip Saltonstall Weld is using a movie camera to record the last moments of his record solo transatlantic crossing in the three-hulled, 51-foot sailing boat *Moxie*. A retired newspaper publisher from Gloucester, Massachusetts, Weld was the winner of last summer's Observer Single-handed Transatlantic Race (OSTAR), an event sponsored by the London *Observer* and the Royal Western Yacht Club of Plymouth, England. He made the 3,000-mile crossing from Plymouth to Newport, Rhode Island in 17 days, 23 hours, 12 minutes—almost three days better than the previous record—and became the first American ever to win the grand prize of solo sailing.

Weld and 87 other OSTAR participants were aided by a French-American space-based monitoring system which reported the yachts' positions throughout the race

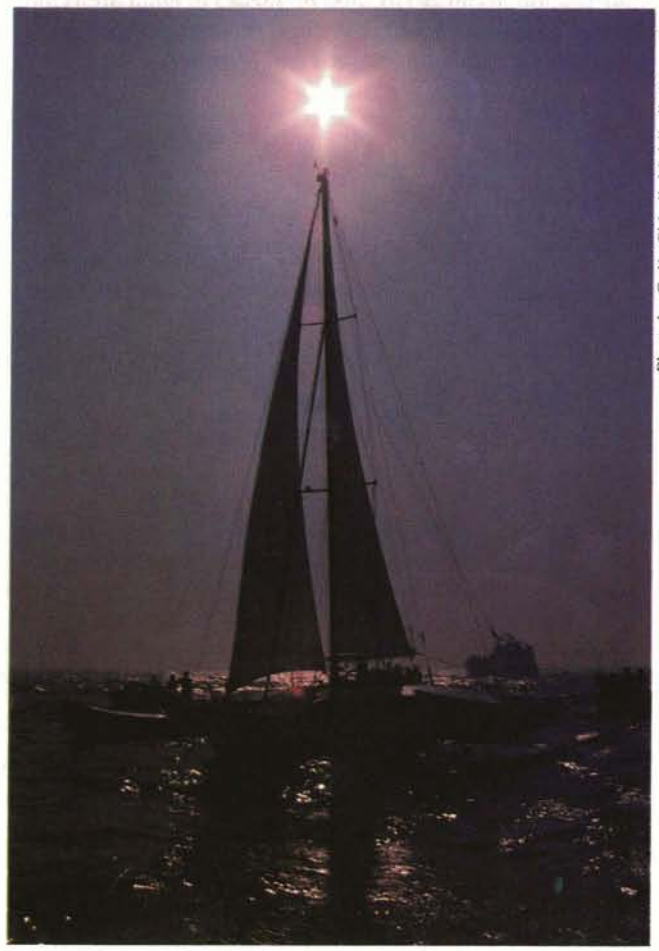


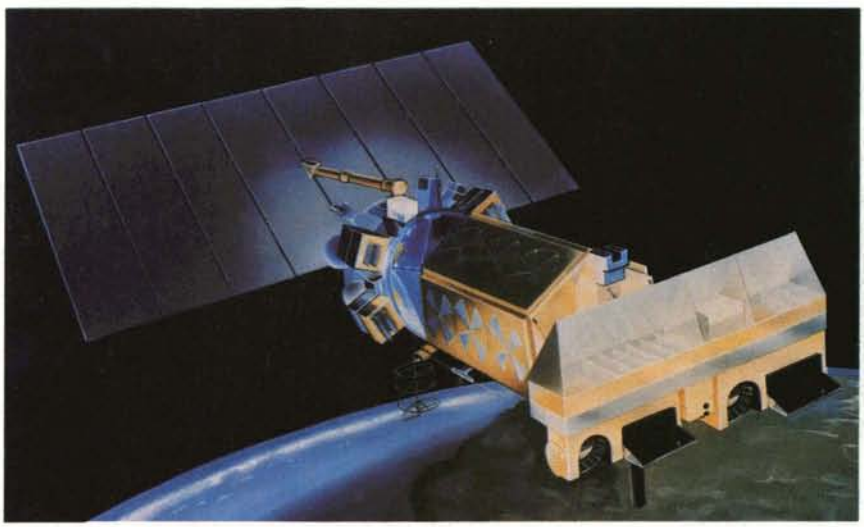
Photo by C. K. Chiodi, Multihulls Magazine

and doubled as an emergency locator service. Called ARGOS, the system is a cooperative project of NASA, the National Oceanic and Atmospheric Administration (NOAA) and the French space research organization Centre National d'Etudes Spatiales (CNES). A key element of the system is the NASA-developed Tiros-N environmental satellite (below) operated by NOAA. The ARGOS system is normally used to collect worldwide oceanographic and meteorological data from portable transmitters on ships, buoys and icebergs. The transmitters report atmospheric pressure, air temperature and water temperature to the satellite, which relays the information to ground processing stations. NASA pioneered this type of data collection system with its Nimbus-6 satellite and a low-power portable transmitter developed by Goddard Space Flight Center. In the ARGOS system, the transmitters and the satellite on-board receiver/computer are French-built.

ARGOS served a dual purpose in the OSTAR race. Since each boat carried a portable transmitter, 88 new sources of oceanographic data became available for the duration of the race. In addition to sending air/water data, each transmitter sent a coded signal identifying the yacht, thus enabling frequent updating of the boats' positions. A sailor in distress could trip a transmitter switch to indicate an emergency, alerting ARGOS personnel who would advise race officials; the latter would then coordinate search/rescue operations with the proper authorities.

Use of ARGOS made the OSTAR competition the most accurately reported sea race ever conducted. Circling Earth in polar orbit, Tiros-N picked up the yachts' signals each time it passed over the North Atlantic. Satellite equipment decoded the signals, recorded the time a signal was received from each boat, and relayed the information to NOAA's facility at Suitland, Maryland. From Suitland, the raw data was passed to the CNES center in Toulouse, France, where it was computer-processed and converted to race progress bulletins detailing the position of each yacht. The bulletins were transmitted to the Royal Western Yacht Club in Plymouth, to the press center in London, and to the finish station at Newport. For each position updating, the entire process took about two hours.

NASA played an emergency role in OSTAR position plotting when NOAA's Suitland computer failed. A data collection and processing station at Goddard Space Flight Center (below right) took over the job of computing and relaying position data to Toulouse for the final three days of the race.



Protective Clothing

Protected by special suits, the firefighters pictured are undergoing training in fire entry—moving directly into flames—which is frequently required in combating fires involving highly flammable products. The fire entry suit, composed of eight separate layers of material, is made by Fyrepel Products, Inc., Newark, Ohio, which manufactures a line of protective clothing for firefighting and for use in industrial jobs where workers are exposed to high heat and such other hazards as steam and hot liquids. Among the fabrics used in the Fyrepel line is one originally developed for astronauts' space suits.

For the Apollo program, Johnson Space Center was looking for a new space suit fabric which had to be thin, light and flexible, yet durable and fire-resistant in high-oxygen environments. At that time, Owens-Corning Fiberglas Corporation, Toledo, Ohio was experimenting with an ultrafine glass fiber yarn called Beta Fiber which seemed to meet the requirements. Johnson contracted with Owens-Corning for further development of Beta Fiber and for research on new fabric weaving and coating techniques. Owens-Corning wove the yarn into a fabric, coated it with Teflon® TFE—manufactured by DuPont Company, Wilmington, Delaware—and tailored it for astronaut wear. Now called Beta Glass®, the material is supplied to Fyrepel by Owens-Corning and incorporated into Fyrepel's Fyretex and Beta-Mex aluminized fabrics. These fabrics are used in the fire entry suits pictured, several other types of protective suits for wear in hot industrial environments, and such accessory items as heat-reflecting curtains for industrial applications.

® Teflon is a registered trademark of DuPont Company.
® Beta Glass is a registered trademark of Owens-Corning Fiberglas Corporation.

Triaxial Fabrics

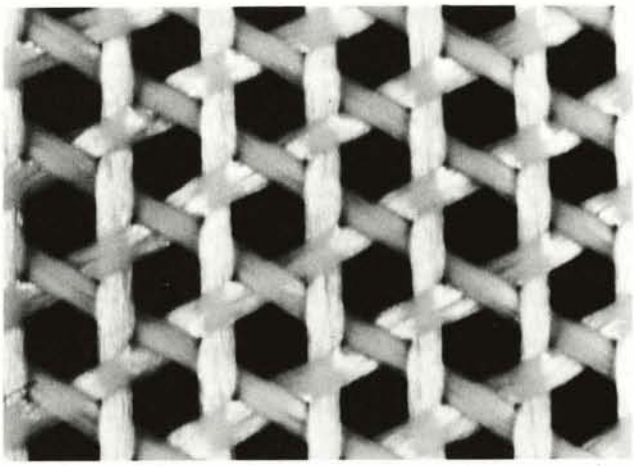
Most fabrics are woven with two sets of yarn intersecting at 90 degree angles; this is called biaxial weaving. The fabrics pictured in highly magnified blowups are triaxially woven from three separate yarn sets whose intersections form equilateral triangles, traditionally the strongest architectural structures. This type of weave assures practically equal strength in every direction; triaxially woven fabric has essentially no bias, or weak dimension, thus offers far greater resistance to tear and shear along with significant weight reduction.

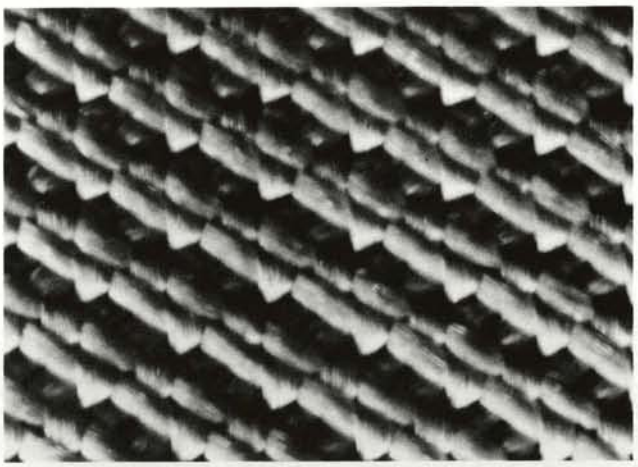
The fabrics shown are typical of the Triax™ line recently introduced by Gentex Corporation, Carbondale, Pennsylvania for applications requiring high strength-to-weight ratio and high material stability—for example, inflatable equipment such as life rafts, life vests, aircraft evacuation slides and helicopter flotation devices; tension structures, such as stadium roofs, and tear-resistant tents; safety clothing; and sailcloth for boats. Triax' ability to accept compound curvatures with no distortion of the weave configuration also makes it useful in manufacturing molded composites, such as diaphragms for emission control valves, air brakes for trucks and locomotives, or automotive and industrial belts. Gentex is initially using polyester, fiberglass and aramid fibers in production of Triax fabrics, but plans to add other fibers to the line.

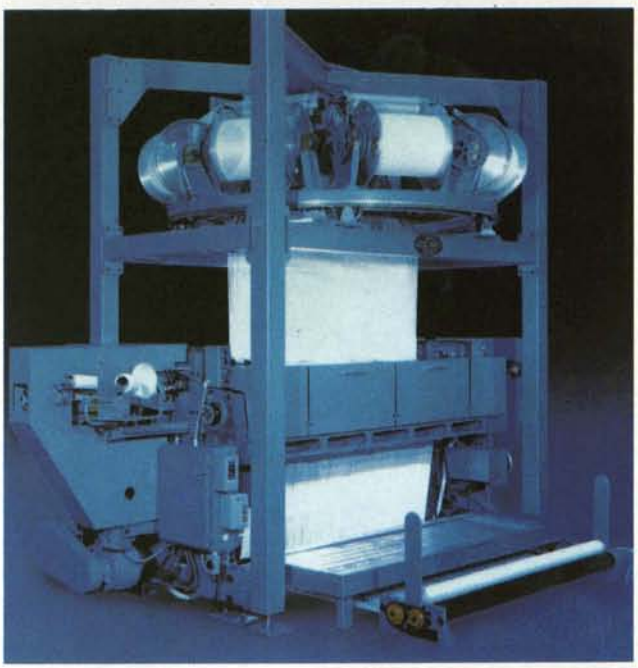
The triaxial weave concept was invented by N. F. Doweave, Inc., formerly of King of Prussia, Pennsylvania but no longer in business. However, NASA sponsorship of advanced research in this field provided the impetus for development of currently available fabrics. Seeking fabrics of high dimensional stability for Space Shuttle pressure suits, Johnson Space Center contracted with Doweave for development of special materials. The Johnson/Doweave effort produced three promising fabrics. One of them, known as BP44P, became the basis for Gentex Corporation's further development and introduction of the Triax line.

Gentex weaving machinery is produced by Barber-Colman Company's Textile Machinery Division, Rockford, Illinois, which acquired sole manufacturing rights to Doweave's triaxial weaving equipment and further developed the machinery. At lower right is the Barber-Colman TW 2000 triaxial weaving machine, which is built in two models; one produces various fabrics in the Basic Weave shown at upper right, the other in the Bi-Plain Weave (center).

™ Triax is a trademark of Gentex Corporation.





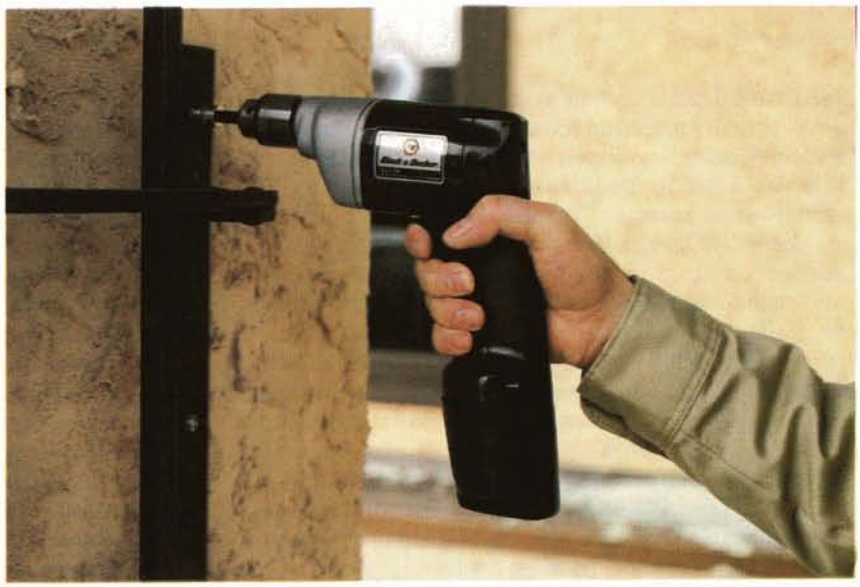


Spinoff from a Moon Tool

Cordless products based on Apollo technology typify aerospace derivatives for home, consumer and recreational use

Among the most important tasks performed by Apollo astronauts on the moon was collection of lunar rock and soil samples for later analysis on Earth. Much of the material was gathered on the surface, but, for comprehensive assay of the moon's crust, scientists also wanted to look at subsurface soil. This necessitated development of a special lunar drill capable of extracting core samples from as much as 10 feet below the surface.

The drill had to be highly efficient to cut through the sometimes hard lunar surface layer, and, like everything that went to the moon, it had to be lightweight and compact. Most importantly, it had to have its own independent power source. Although the tool could have operated on power from the Lunar Module, the astronauts' home and operating base, scientific requirements dictated sampling at diverse locations, some of them far from the base.



The job of developing the drill was entrusted to The Black & Decker Manufacturing Company, Towson, Maryland, which responded with a battery-powered, magnet-motor system that proved successful in lunar work. In the course of the development, Black & Decker used a specially-developed computer program to optimize the design of the drill's motor and insure minimal power consumption. That computer program, along with the general knowledge and experience gained in developing the drill, provided a stronger technology base for continuing company development of battery-powered implements. Black & Decker has refined the original technology and now produces a line of consumer, medical and industrial cordless tools and appliances.

The most recent device to reach the commercial market is the "Dustbuster," a miniature, hand-held vacuum cleaner for the home or auto. The Dustbuster has no hose, no cord, is only 14 inches long and weighs less than two pounds; thus, says the company, it offers a convenient means of quick cleanup after spills without wrestling the standard home vac out of the closet. The Dustbuster also provides an easy way to clean hard-to-reach places where dirt and crumbs accumulate, such as corners, shelves, stairs, around plants and behind cushions. The mini-vac comes with a storage bracket that also serves as a recharger; plugged into a home outlet, it charges the nickel-cadmium batteries when the appliance is not in use.

Along with the Dustbuster, Black & Decker's line of home-use cordless implements includes drills for the handyman or hobbyist, shrub trimmers and grass shears, all of which are rooted in Apollo technology. The company also manufactures a number of cordless tools used in the sheet metal, automobile and construction industries, and a line of cordless orthopedic instruments for hospital use. The latter are separately covered on page 94.

Black & Decker's Dustbuster (opposite page), a cordless miniature vacuum cleaner for quick pickup in hard-to-reach places, traces its origin to a battery-powered lunar drill developed by the company for the Apollo program. Among other Black & Decker cordless products rooted in the same technology is a hand-held home drill (upper photo), also usable in construction tasks (right) where a power source is not readily available.

Temper Foam

More than a decade ago, in a program designed to improve crash protection for airplane passengers, Ames Research Center developed a foam material with unusual properties. Used for padding aircraft seats, the material—now known as Temper Foam®—not only provides better impact protection but also enhances passenger comfort on long flights because it distributes body weight and pressure evenly over the entire contact area. Called a "memory foam," it flows to match the contour of the body pressing against it and returns to its original shape once the pressure is removed. As a shock absorber, a three-inch foam pad can absorb the impact of a 10-foot fall by an adult.

Temper Foam has become one of the most widely used spinoffs from NASA technology. Examples of its many applications include seat cushioning for transportation vehicles, padding for furniture, and a variety of athletic equipment such as body pads and chest protectors. Medical applications include wheelchair padding, artificial limb socket lining, finger splint and hand padding for burn patients, special mattresses for the bedridden, and dental stools. Production and sales rights are owned by Temper Foam, Inc., Cincinnati, Ohio and Boston, Massachusetts. The material is manufactured under license by the Dewey and Almy Division of Grace Chemical Corporation, Woodbury, New Jersey. The distributors—Kees Goebel Medical Specialties, Inc., Cincinnati, and Alimed, Inc., Boston—sell Temper Foam in bulk form to fabricators, who trim it to shapes required by their customers.

One such fabricator is Expanded Rubber and Plastics Corporation, Gardena, California, which supplies products for some new applications illustrated by the accompanying photos.

Below left is the cockpit of the Wing Derringer, a two-place twin-engine lightplane produced by Wing Aircraft Company, Torrance, California. Its seats are

constructed of molded fiber glass and padded with Temper Foam to reduce pilot and passenger fatigue on long flights.

At left is a product known as Accu-Back,® manufactured by Accu-Back, Inc., Gardena, California. Accu-Back is an orthopedic seat for those who spend long periods in wheelchairs, office chairs, auto or truck seats. Responding to body heat and temperature, Accu-Back's Temper Foam cushion distributes pressure evenly, providing a custom fit for the individual back and encouraging correct spinal disc alignment. The oval-shaped parts are lumbar pads, mounted on the back panel in a slightly angled fashion to duplicate the natural contours of the back; they can be moved up and down to suit personal preference. An optional carry case makes the five-pound Accu-Back a portable back support for sporting events, the theater, in jetliners, buses or trains.

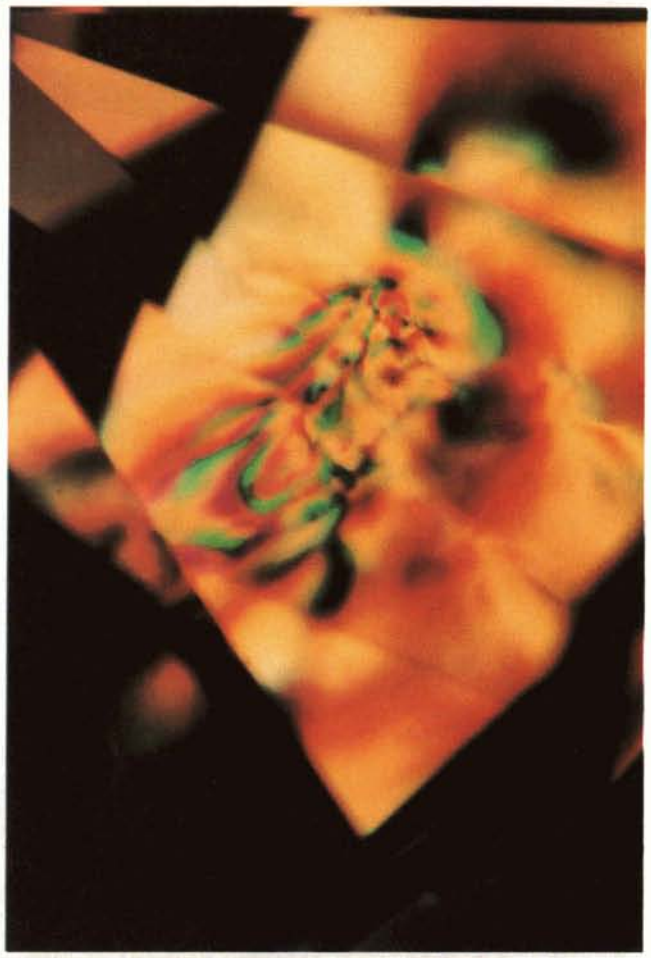
In another Temper Foam application, shown below, the material is used in the cushions of the helicopter operated by the Huntington Beach (California) Police Department for greater pilot comfort and less fatigue; department officials attest that the cushioning has enabled an increase—from one hour to two—in patrol flying time, due to reduced vibration effect. The shock absorbing qualities of Temper Foam also offer greater protection in hard landings.

® Temper Foam is a registered trademark of Temper Foam, Inc.
® Accu-Back is a registered trademark of Accu-Back, Inc.

Gem Analysis

Below, Robert S. Peebles is examining a gem specimen through an instrument—called a cathodoluminoscope—that magnifies the specimen and also produces heat-generated light emissions that bring out special features of importance in gemological analysis. Peebles is president of World Gem Laboratory, Minden, Nevada, which appraises gems, leases gemological equipment and conducts research toward more effective methods of analyzing gems and minerals.

At right is a magnified view of a natural diamond under heat-induced luminescence. The blue-green and red areas indicate hot spots where the gem would



fracture if stressed. Examinations like this can reveal whether a stone can be successfully cut, a major factor in a gem's value. World Gem Laboratory uses the cathodoluminoscope for such purposes as study of growth and strain patterns in diamonds, detection of dyes in jade, and analysis of the growth and structure of rubies and sapphires. Used in combination with other tests, these analyses can separate synthetic from natural gems, a matter of prime economic importance because the value of a natural gem can be 20 times that of a synthetic.

World Gem Laboratory benefited from NASA technology developed by Jet Propulsion Laboratory (JPL) to help crime laboratories assess physical evidence. The JPL technique utilizes the phenomenon of thermoluminescence—heat-induced light emissions—to analyze the composition of evidence materials, allowing determination of whether two items issued from the same or different sources. Thermoluminescence and cathodoluminescence are closely related in many respects, and there is very little information available on either subject. So when Peebles read a published account of JPL's work, he sought and received detailed technical information about the NASA development. He credits the information with substantially increasing his general understanding of luminescence, hence his ability to develop new analytical techniques.

Hang Gliders

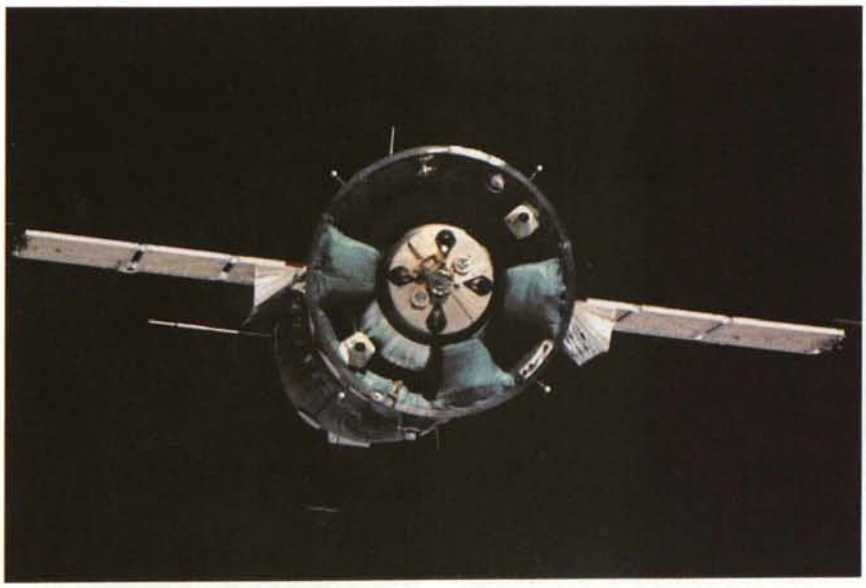
The hang gliders pictured are built by U.S. Moyes, Inc., Bridgman, Michigan, whose "kites" have set a number of records, including last year's world flexible wing distance record of 111 miles. The Moyes design is based in part on NASA technology developed as a once-considered alternative to parachutes for manned spacecraft post-orbital descent systems.

Hang gliders are modern versions of 19th century man-carrying kites and there have been many experimenters. Consensus holds that one of the foremost contributors to the technology was Francis M. Rogallo, a former employee of NASA and its predecessor organization, the National Advisory Committee for Aeronautics. In the latter 1940s, Rogallo and his wife Gertrude began research on flexible, controllable, fabric airfoils with a delta—V-shaped—configuration intending them for use on inexpensive private aircraft. The Rogallos were issued a flex-wing patent in 1951 and they refined their designs during the 1950s. When NASA was in the early stages of manned spacecraft development, the Rogallo wing aroused interest as a possible means of lowering a spacecraft to Earth after re-entry; its potential advantage over parachutes was the ability to glide over long distances to a controlled touchdown on land rather than in the ocean. Ultimately, NASA decided to stick with advanced parachute descent systems—but in the interim the agency conducted extensive wind tunnel test and development of Rogallo wings and substantially broadened the flexible airfoil technology base.

While this work was under way, Australian John Dickenson was experimenting with a kite design for water skiing. A magazine article on the Rogallo wing suggested to Dickenson a safer, more stable design than he had previously considered. Later, Dickenson obtained detailed technical information from NASA. The basic design of the kite was his own, but some of the Rogallo technology—particularly the airfoil frame—was incorporated. In 1967, Dickenson met Bill Moyes, who formed an Australian company to build hang gliders. The Dickenson kite served as prototype for the Australian Moyes line and as forebear of the models later produced by U.S. Moyes. The latter company is now the sixth largest U.S. manufacturer of hang gliders.

Breaking the Language Barrier

Heading a group of technology transfers in the field of computer processing is a space-spurred electronic translation system



The spacecraft pictured is a Soviet Soyuz, photographed by an American Apollo crew as the two craft maneuvered toward a historic docking in orbit. Preparations for the mission entailed large-scale informational exchange, accomplished by a computerized translation system. Apollo-Soyuz thus provided impetus to development of a commercial machine translation system known as SYSTRAN II.

In the summer of 1975, an American Apollo and a Soviet Soyuz spacecraft docked in orbit, the first international space linkup. The mission—which proved highly successful—was intended as a first step in development of internationally compatible equipment and techniques, toward the day when spacecraft of any nation could dock together for operational or rescue purposes.

Apollo-Soyuz was a complex project that needed three years of preparation for study of the many Soviet/American differences in design and operational techniques, and for joint development of an airlock to allow the crews to move from one spacecraft to the other. For the benefit of astronauts, cosmonauts, scientists, engineers and ground controllers, each nation provided the other a voluminous library of technical literature —written, of course, in the language of origin. That posed a first class dilemma; there probably were not enough technically qualified translators in the world to convert the material from one language to the other in the allotted time.

Johnson Space Center (JSC) found a solution in the person of Dr. Peter Toma, president of LATSEC, Inc. and the World Translation Center, La Jolla, California. A pioneer in computerized language translation, Dr. Toma had earlier developed a basic software package—called SYSTRAN—and worked on a Russian-to-German translation system. He had also developed, for the U.S. Air Force, software for translating Russian into English.

Under JSC contract, Dr. Toma undertook development of a two-way software package—Russian to English and English to Russian—for Apollo-Soyuz. For the Russian to English translations, he was able to draw on the technology he had developed for the Air Force. Converting English to Russian, however, presented a formidable challenge. Russian is a "fully-inflected" language wherein word meanings are altered, in precise fashion, by the addition of prefixes, infixes and suffixes; parts of speech and the relationships between adjectives and the nouns they modify are virtually always clear. English is much more subtle; the meaning of a statement is influenced by the parts of a sentence preceding or following a particular word or phrase. Many

language experts had predicted that machine translations from English would be next to impossible.

Dr. Toma proved them wrong. His two-way Apollo-Soyuz software package was highly satisfactory and it contributed substantially to the success of the mission. His breakthrough in translating English to a fully-inflected language, coupled with the demonstration of software reliability in a large-scale project, spurred commercialization of machine translation.

One of Dr. Toma's first commercial customers was Xerox Corporation, Rochester, New York. Xerox markets its products internationally, thus needs translation of service manuals into several languages. Seeking to improve its competitive posture by reducing translation and printing time, Xerox contracted with Dr. Toma's World Translation Center for translation software. The company is currently making translations from English into French, Spanish, Italian and Portuguese and is planning expansion into other languages.

In 1976, Dr. Toma licensed World Translation Company of Canada (WTCC) Limited, Ottawa, Ontario to handle North American marketing and commercial support activities for the SYSTRAN system. WTCC was formed by a group of Canadian investors who saw a broad market for electronic translation in growing corporate multinationalism and in Canada's Official Languages Act, which requires publication of government and other documents in both French and English. Dr. Toma and WTCC still work together; the result of their collaboration is SYSTRAN II.

The key element of SYSTRAN II is a computer program—one of the longest ever written, with half a million lines of instructions—backed by a computerized dictionary which contains terminology, technical expressions, grammatical rules and semantic principles. The text to be translated is fed into the computer, which analyzes it for syntax and semantics, then produces—in printout form—an accurate version of the text in the target language. The computer's draft is refined by human translators, whose editing is also computerized. The system then produces a magnetic tape ready for photocomposition.

WTCC says that SYSTRAN II will generally increase the output of a human translator by five to eight times, thus affording significant cost savings by allowing a large increase in document production without hiring additional people. Extra savings accrue from automatic production of camera-ready copy.

SYSTRAN II applications include translation of service manuals, proposals and tenders, planning studies, catalogs, lists of parts and prices, textbooks, technical reports and education/training materials. The system is operational for six language pairs. In addition to Russian/English and English/Russian, they include translations from English to French, Spanish and Italian and from French to English. Six other pairs—English to German, Portuguese and Arabic, German to English, French and Spanish—have been successfully demonstrated and are being improved. Japanese to English and English to Japanese are in process of development.

Xerox Corporation's experience exemplifies the system's utility. Xerox, which has a 10-person translation group and a high annual volume of manual production, finds that its machine translations take only 20 percent of the time otherwise required, even with allowance for the time spent on human editing of the computer's draft. There is an additional saving in formatting time; the translated readout retains the indentations, paragraphing and other features of the input copy, hence—after editing—is ready for printing. In addition to Xerox, other major SYSTRAN users include General Motors of Canada, Bell Northern Research of Canada, the U.S. Air Force and the European Commission.

SYSTRAN II "reads" a document in one language and produces a printout in the target language. Using a computer terminal, a human translator (below) refines the printout. The end product is a translated and edited magnetic tape ready for printing.

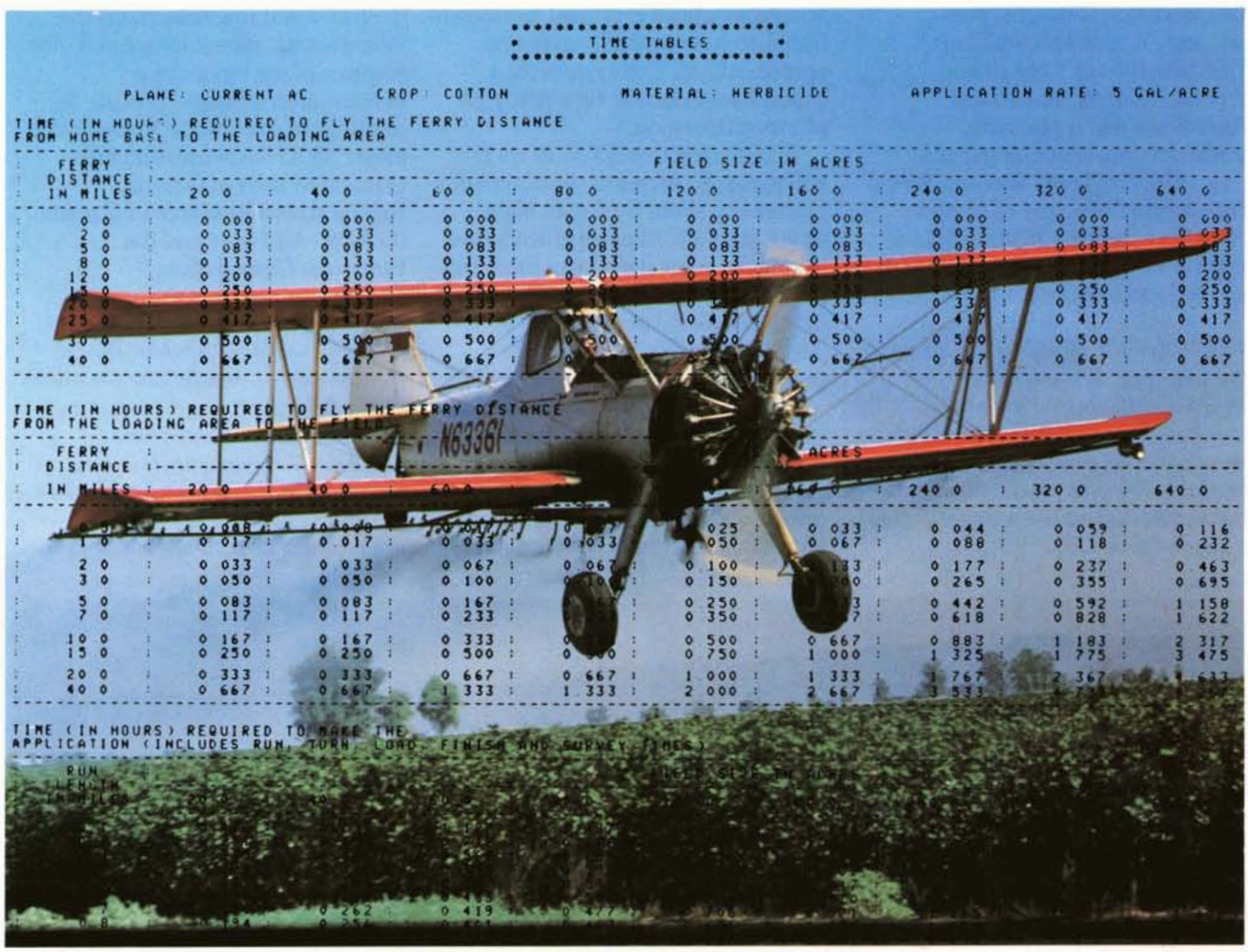
At the University of Petroleum and Minerals in Saudi Arabia, David Burden (right), senior vice president of World Translation Company of Canada, demonstrates how SYSTRAN II can translate English language material into Arabic with accuracy, consistency and appreciable cost savings.

Ag-air Service

Agricultural aerial application—"ag-air" for short—is a billion dollar industry in the United States, involving more than 10,000 aircraft spreading insecticides, herbicides, fertilizer, seed and other materials over millions of acres of farmland. It is an extremely varied industry and no two ag-air businesses are exactly alike. An operator may have one airplane or several. He may spray a 20-acre field one day and a 500-acre field the next. The target field may be close to his base or some distance away, a factor in airplane fuel expenditure. Crops treated differ from one job to the next, as do the materials applied—and costs of both materials and fuel change rapidly. In this unique, multivariable business atmosphere, ag-air operators face unusual problems. For example, it is difficult for an operator to estimate costs accurately and thus decide what to charge, or to determine which airplane can handle which assignment most efficiently.

To fill an informational need in the industry, Econ, Inc., a Princeton, New Jersey economics research firm is providing a computerized service designed to improve business efficiency in two key decision-making areas: choice of aircraft and determination of charge rates based on realistic operating cost data. The Ag-air Cost Effectiveness Analysis Service is a spinoff from a NASA study—performed by Econ—intended to help NASA chart a program of technology development in areas most beneficial to operators and manufacturers of agricultural aircraft.

In the course of the study, Econ built a comprehensive data base on worldwide ag-air operations, including aircraft costs, materials costs, job times and many other variables. Updated and expanded, this information served as the keystone for Econ's economic analysis service. Econ asks subscribers to fill out detailed forms describing the characteristics of aircraft in service or planned, together with information about the operator's applications—types of crops treated, materials used, field sizes, hours flown and a variety of other factors. For a moderate fee, Econ supplies a custom-tailored computer printout which allows easy computation of time, cost and charge for a specific job. Also provided is a cost/productivity comparison of various types of ag-aircraft, enabling the operator to select the craft best suited to his particular business mix.



Power Plant Valves

In these photos, a mammoth 7½-ton valve (left) and a gas-hydraulic actuator for quickly closing large valves (right) are undergoing shock and vibration testing on a "shake table" at Wyle Laboratories, Huntsville, Alabama. Intended for use in a nuclear power plant, they were subjected to enormous forces simulating the effects of a severe earthquake. Government regulations require that nuclear power generating equipment demonstrate ability to survive earthquake conditions.

The units shown are representative of a line of valve products manufactured by Rockwell International's Flow Control Division, Pittsburgh, Pennsylvania, for use in nuclear, fossil fuel, chemical and coal gasification plants. In designing such equipment, Flow Control Division uses the NASTRAN® (NASA Structural Analysis) computer program, one of many programs supplied by NASA's Computer Software Management and Information Center (COSMIC)® as a service to industry. The NASTRAN program is employed to identify high stress areas in valve products and the mechanical configurations necessary to accommodate them. It is also used in seismic and vibration analysis of valves to establish design adequacy under severe conditions, such as those which might occur in an earthquake. Flow Control Division reports that the NASTRAN program offers significant savings in analysis effort compared with other analytical approaches.

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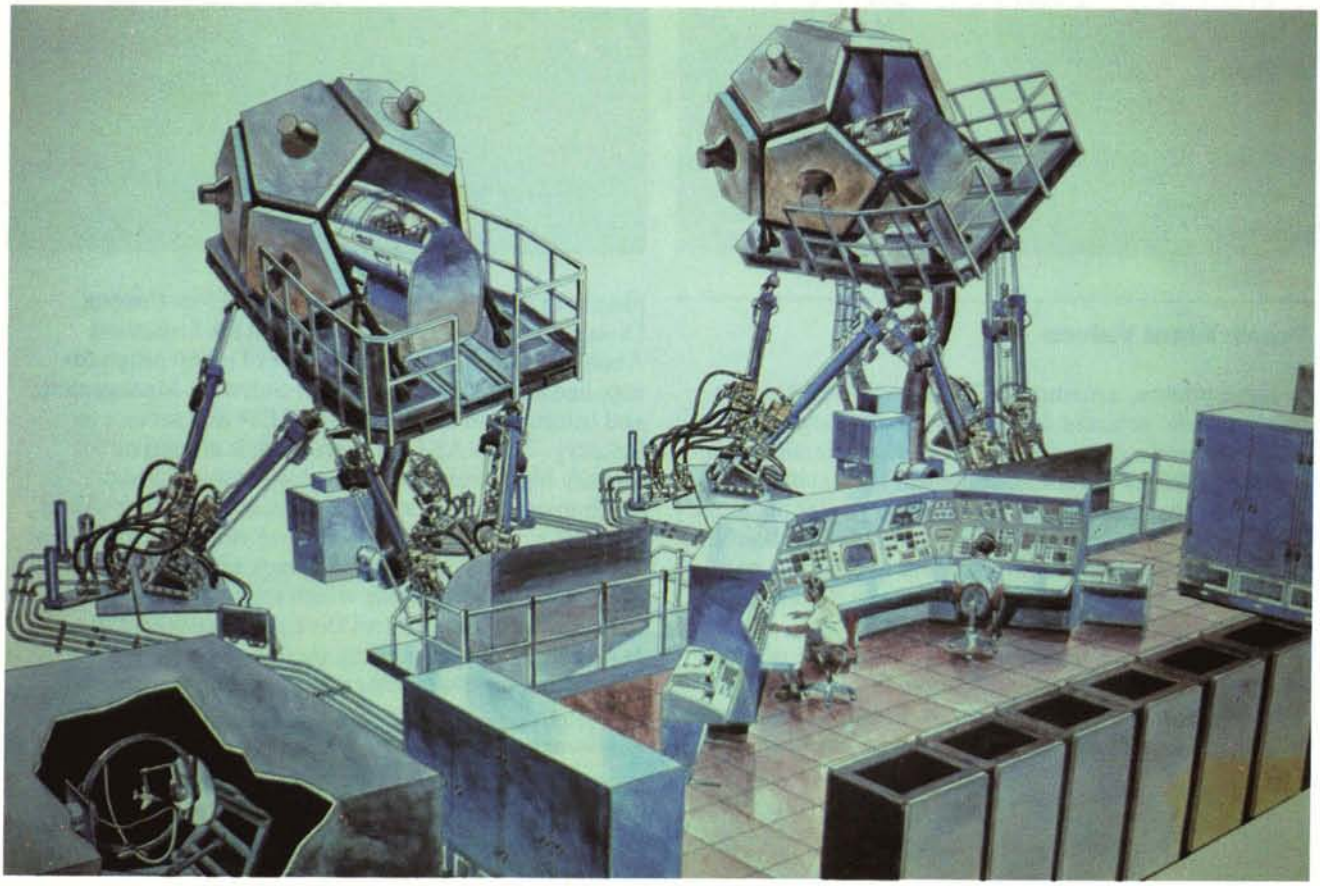
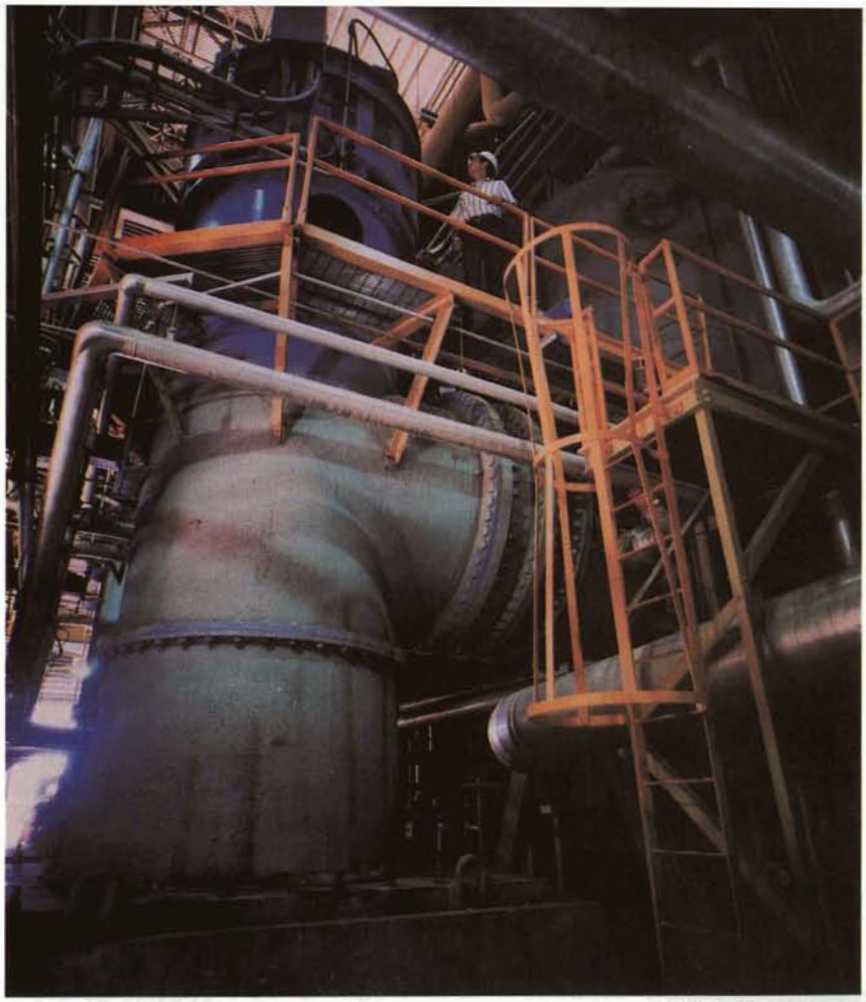
Air Combat Simulator

The system pictured is the Simulator for Air-to-Air Combat (SAAC) used by Air Force pilots undergoing Air Combat Engagement Simulation training at Luke Air Force Base, Arizona. Under the supervision of an instructor who monitors the action from a console, student pilots "fly" simulated Air Force fighters in an engagement with a simulated target whose maneuvers are directed by a computer program. The SAAC was built by Link Division of The Singer Company, Binghamton, New York.

The two-cockpit configuration was designed to train fighter pilots in one-on-one basic fighter maneuvers with an instructor pilot in one cockpit and a student in the other. Through enhancements to computer software developed by Link for simulation of "two-versus-one" combat, two trainees can simultaneously engage a computer driven target, thereby doubling the training utility of the simulator. The two-versus-one computer program is an adaptation of a NASA-developed program—commonly called One-on-One Adaptive Maneuvering Logic (AML)—supplied by NASA's Computer Software Management and Information Center (COSMIC). Located at the University of Georgia, COSMIC maintains a large library of computer programs developed by NASA and other technology-generating government agencies and makes them available to industry at a fraction of their original cost—thus saving users the time and expense of developing entirely new programs. By adapting COSMIC's AML for two-versus-one simulation, Link Division was able to reduce software and other design/development costs.





Pump Flow Analysis

Among its broad product line, Ingersoll-Rand Company, Woodcliff Lake, New Jersey manufactures large circulating pumps such as the one shown above; this 4,000 horsepower unit supplies the cooling water for a power plant in the southeastern United States. In designing impellers for the pumps, the company's Pump Group makes use of a NASA-developed computer program supplied by NASA's Computer Software Management and Information Center (COSMIC) at the University of Georgia.

Known as MERIDL, the program performs flow analysis calculations which permit designers to evaluate the performance and efficiency characteristics to be expected from the pump's impeller. MERIDL also provides information that enables a trained hydraulic engineer to make design improvements. Through use of the COSMIC program, the company was able to avoid the cost of developing new software and to improve some product design features.

Ingersoll-Rand's Research Center, Princeton, New Jersey acquired the program from COSMIC and assisted company hydraulic designers in using it in the design process. An example of a product whose design was aided by MERIDL is the unit shown at right, an impeller for a large vertical circulating pump used to pump sea water into a desalinization plant in Saudi Arabia. Ingersoll-Rand also uses a companion COSMIC program called TSONIC for analyzing flow velocities in pumps, compressors and turbines.

Sub-ocean Drilling

For the past 20 years, the National Science Foundation (NSF) has been conducting a highly successful program involving exploration of Earth's crust by drilling beneath the ocean floor and bringing up core samples. The program's aims include substantiation and refinement of the plate tectonic theory, which holds that Earth's continents and oceans continuously change; determining the impact of such changes on climate and ocean circulation; and establishing the geological framework in which natural resources are formed and distributed.

Last year, NSF initiated a new phase of exploration, a 10-year effort—jointly funded by NSF and several major oil companies—known as the Ocean Margin Drilling Program (OMDP). Described as one of Earth's last scientifically unexplored frontiers, the ocean margin is the region of Earth's crust between the continental shelf and the deep ocean abyss. Exploring it demands a ship with capabilities beyond those of existing drillships; it must drill in 13,000 feet of water to a depth 20,000 feet below the ocean floor. To meet these requirements, NSF is considering the conversion of the government-owned mining ship *Glomar Explorer* to a deep ocean drilling and coring vessel. *Glomar Explorer* is shown at left in its mining ship configuration. Below is the ship's large

"moon pool" through which drilling equipment can be lowered; the moon pool can be opened or closed to the sea by gates which slide on rails along the hull bottom. The photo above shows the computer control center where technicians monitor undersea operations and the "dynamic positioning" system which automatically holds the ship in precise position over the work site.

The decision to convert the ship was prefaced by a feasibility study, performed for NSF by Donhaiser Marine, Inc. (DMI), Houston, Texas, a naval architect/engineering firm specializing in services to the offshore petroleum industry. In the study, which analyzed the ship's characteristics for OMDP suitability and evaluated conversion requirements, DMI used a computer program supplied by NASA's Computer Software Management and Information Center (COSMIC). With the COSMIC Ship Motion and Sea Load Computer Program, DMI was able to perform analysis which could not otherwise have been accomplished. The analysis, correlated with full scale sea tests, confirmed *Glomar Explorer's* suitability. Engineering design work is under way and *Glomar Explorer,* if approved for conversion, is expected to begin operations as a drillship in 1984.

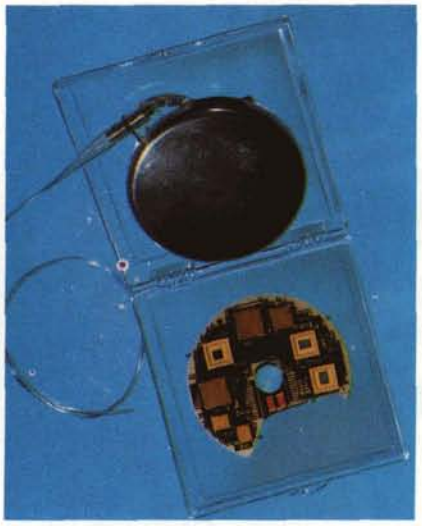
Space-derived Health Aids

Human-implantable devices for improved disease control highlight a sampling of spinoffs in the field of health and medicine

A cardinal rule of spacecraft design is that everything destined for orbit must be superefficient yet as small and as light as technology permits. This is especially true of the family of small satellites, some no larger than a beach ball, intended to meet specific research objectives at minimal cost. In developing these models of compactness, researchers have performed astonishing feats of "microminiaturization," reducing electronic and other components to incredibly tiny dimensions.

A leader in small spacecraft design is the Applied Physics Laboratory (APL) of Johns Hopkins University, Howard County, Maryland. Not coincidentally, APL is also a leader in development of medical systems, particularly devices that can be implanted in the human body. The organization's work in transferring microminiaturization and other space technologies to the field of medicine is one of the outstanding examples of the spinoff process.

The latest of APL's developments, scheduled for first human implant this year, is the Programmable Implantable Medication System (PIMS). Being developed in cooperation with Goddard Space Flight Center (GSFC) and several commercial firms, PIMS is a microminiaturized, computer-directed system for continuous delivery of medication to target organs, in precisely controlled amounts, from a source within the patient's body.

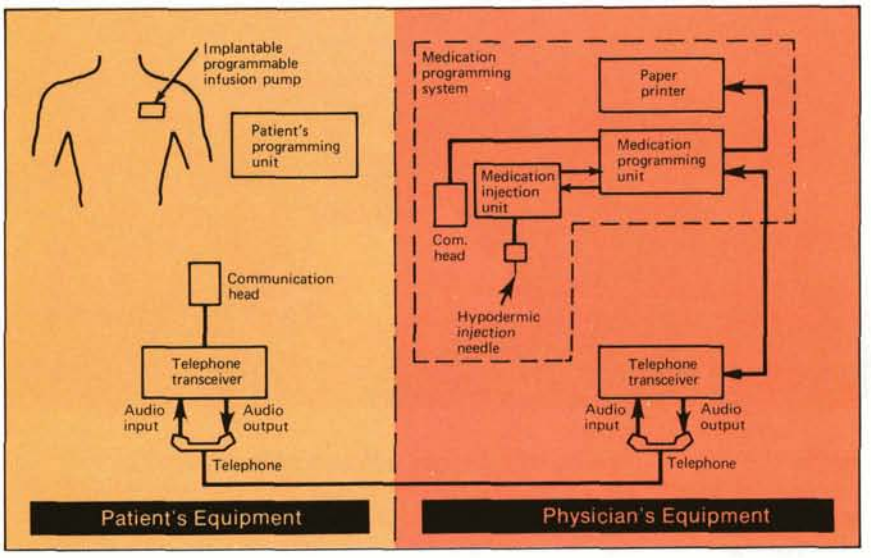


This device is a computerized pumping unit, part of a new Programmable Implantable Medication System for continuous delivery of medication—insulin, for example—from a source within a patient's body. About the size of a woman's compact, it contains a reservoir of medication, a tiny pump, a tube leading to the target area of the body, a battery, and the microminiaturized electronic system shown in the lower view.

One important application is treatment of diabetes, wherein a malfunctioning pancreas fails to create enough of the hormone insulin to keep the amount of sugar in the blood at a normal level. Many diabetics—more than a million in the United States—need daily or twice daily injections of insulin. PIMS, serving as an electronic artificial pancreas, could free them of this daily ritual and provide further benefit in better control of the body's blood sugar level. Research with external pumps indicates that metering of insulin in tiny amounts over a long period of time is more effective in normalizing many aspects of metabolism than is the injection method. With a pumping system like PIMS, it could be possible to minimize complications of severe diabetes, such as eye, kidney and blood vessel damage caused by fluctuating blood sugar levels.

The key element of PIMS is the Implantable Programmable Infusion Pump (IPIP), contained in a package about the size of a woman's compact and implanted in the shoulder or abdominal area. IPIP consists of a mini-computer that controls the dosage, a reservoir for the medication, a tiny pump, a plastic tube leading from the pump to the target organ, and a lithium battery to power the electronics and pump.

The other major PIMS segment is the Medication Programming System (MPS) in the physician's office. The MPS includes an electronic system for programming IPIP's medication delivery according to the patient's needs. Programming is accomplished by wireless telemetry—a space technology—in which command signals are sent to IPIP by means of a



The diagram shows how a physician can communicate via telephone line with the implanted pump's computer. The computer reports stored information to a receiver in the doctor's office. The physician can reprogram the system—change the dosage—by means of an electronic programmer. Refilling the medication reservoir is accomplished—in the doctor's office—by hypodermic injection.

transmitting antenna called a communication "head." The physician can also "interrogate" the computer; he can, for instance, ask how much medication remains in the reservoir and get a reply in the form of a printed readout.

Since both patient and physician could have communication heads hooked up to a telephone transceiver, visits to the doctor's office would be minimized. The patient places the communication head over the implanted device, presses a button, and the physician is in touch with IPIP's computer. The physician can interrogate the computer and reprogram the medication flow rate after determining how the patient is responding to treatment. In doctor/computer communication, another space technology—called pulse coded modulation—plays a safeguarding role: IPIP will accept only properly coded instructions and will not respond to false signals generated by other sources.

When the computer reports its medication is running low, the patient is summoned to the physician's office for a refill, accomplished by hypodermic injection through IPIP's self-sealing membrane. The reservoir is designed to hold enough medication for long term treatment, the time varying with the application and the dosage. In diabetes treatment, for example, the patient would have about a three-month supply.

A particularly important feature of PIMS is a unit which enables the patient to change his own dosage. Insulin recipients, for example, need more medication after meals. The IPIP is programmed to understand signals describing six types of meals. Holding a small device over the implant, the patient could, for example, dial "medium mixed meal" and the pump would temporarily increase the insulin dose, then resume its normal output.

Although insulin delivery is the most immediate application, PIMS offers similar advantages in treatment of other diseases where long term injection from an internal source seems indicated. Examples include programmed metering of blood-thinning drugs to prevent coronary occlusion or stroke; chemotherapeutic drugs for inoperable tumors; methadone for drug addiction; antabuse for alcoholism; or opiates for pain.

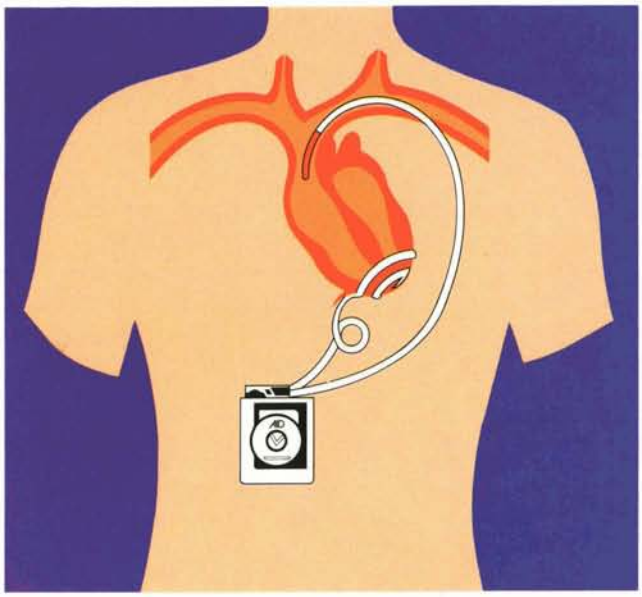
PIMS involves the work of several cooperating organizations in addition to APL. GSFC is providing program management and technical expertise. Pacesetter Systems, Inc., Sylmar, California, a medical equipment manufacturer, is providing part of the funding and will produce the system for the commercial market. Parker-Hannifin Corporation's Biomedical Products Division, Irvine, California is developing the fluid handling system. Novo Research Institute, Copenhagen, Denmark is developing a special, concentrated insulin to reduce the volume needed for long term dosage.

PIMS is one of a number of implantable devices developed by APL, in cooperation with GSFC and other groups, over the past decade. Some of the others are described on the following pages.

Wearer of a "Pacer"—a rechargeable cardiac pacemaker—the child is shown with the recharging unit. First of a series of implantable systems developed by the Applied Physics Laboratory (APL) of Johns Hopkins University, the Pacer represented a major advance in heart-assist devices in that its rechargeability eliminated the recurring need for surgery to implant a new battery. Produced by Pacesetter Systems, Inc., the Pacer is based on technology developed for spacecraft electrical power systems.

Pacesetter Systems and APL jointly developed the advanced cardiac pacing system shown, which permits a physician to reprogram a patient's implanted pacemaker without surgery. Called Programalith®, the system consists of the pacemaker (foreground) together with a physician's console containing the programmer and a data printer. The physician communicates with the pacemaker by means of the communicating head (at left), which is held over the patient's chest; signals are transmitted by wireless telemetry. The two-way communications capability allows the physician to interrogate the pacemaker as to the status of the heart, then to "fine tune" the device to best suit the patient's needs, which may change over time with changes in physical condition. Programalith incorporates space technologies used to send coded instructions or queries to satellites and to receive replies from the satellites.

®*Programalith is a registered trademark of Pacesetter Systems, Inc.*



A spinoff from miniaturized pace circuitry is the new heart-assist device shown above, the AID® implantable automatic pulse generator. Designed to prevent thousands of deaths caused by the erratic heart action known as ventricular fibrillation, the AID pulse generator monitors the heart continuously, recognizes the onset of fibrillation, then administers a corrective electrical shock. Included in the implantable unit are a mini-computer, a power source, and two electrodes which sense heart activity.

Now undergoing clinical test, the AID pulse generator was developed by Medrad Incorporated and Intec Systems, Inc., both of Pittsburgh, Pennsylvania, in conjunction with Drs. M. Mirowski and M. Mower of Sinai Hospital and Johns Hopkins University Hospital, both of Baltimore, Maryland. With NASA funding, APL conducted an independent evaluation to assure that the system was ready for trials in selected patients who have high risk of experiencing ventricular fibrillation. APL also developed an associated system. Shown at top right, it includes an external recorder to be worn by AID patients and a physician's console to display the data stored by the recorder. This system provides a record of fibrillation occurrence and the ensuing defibrillation, information important to the physician in prescribing further treatment.

®*AID is a registered trademark of Medrad Incorporated.*

A cooperative development involving NASA, APL, Pacesetter Systems, several medical centers, and industrial participants is the Programmable Rechargeable Neuropacemaker (PRN), an implantable human tissue stimulator designed to provide relief to patients with disorders treatable by electrical stimulation—for example, back, leg and arm pain, cancer pain, and multiple sclerosis. A spinoff from spacecraft electronics technology, PRN allows the physician to adjust stimulation according to the treatment needs of the particular disorder. He does so by means of the command programmer pictured, which sends signals to the implanted device by telemetry.

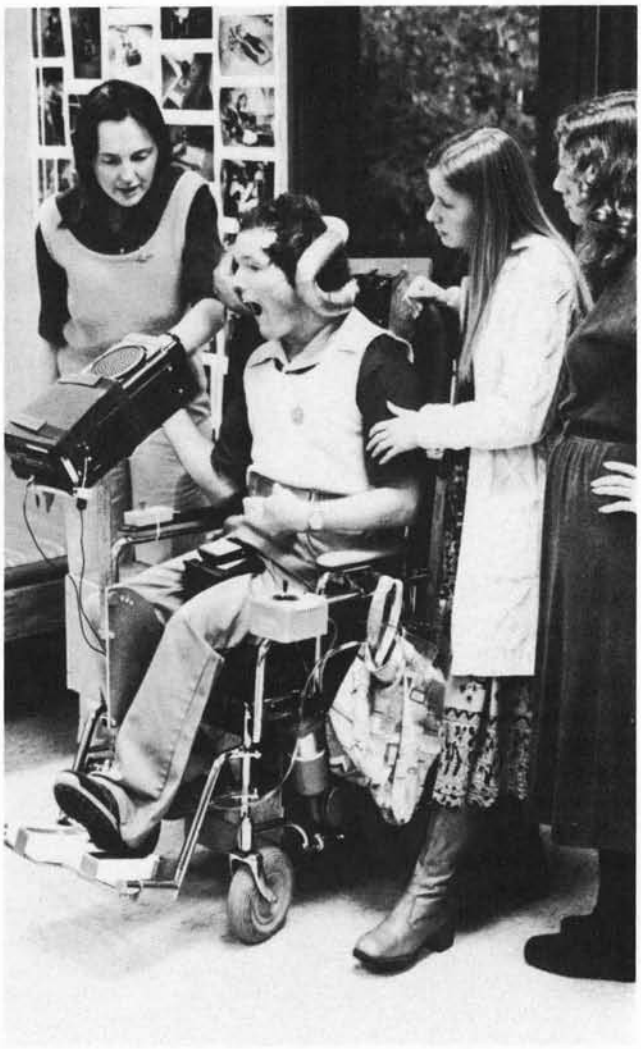
Bacteria Counter

In the photo, a laboratory technician is using an instrument called the ATP Photometer to make a rapid and accurate count of the bacteria in a body fluid sample. Produced commercially by SAI Technology Company, a division of Science Applications, Inc., San Diego, California, the ATP Photometer stems from technology originally developed by Goddard Space Flight Center for NASA life-detection missions to other planets.

The instrument provides information on the presence and quantity of bacteria by measuring the amount of light emitted by the reaction between two substances. The substances are ATP—adenosine triphosphate, which is present in all living cells—and luciferase, an enzyme derived from fireflies which releases light only in the presence of ATP. These reactants are applied to a human body sample—urine, blood or spinal fluid—and the ATP Photometer observes the intensity of the light output, displaying its findings in a numerical readout. Total assay time, including preparation of the body sample, is usually less than 10 minutes; this represents a significant time saving in comparison with the standard laboratory technique involving culture preparation and microscopic examination of the culture.

In addition to medical applications, the ATP Photometer has been successfully employed in such other uses as measuring organisms in fresh and ocean waters, in determining bacterial contamination of foodstuffs, in the beverage industry for biological process control, and in assay of activated sewage sludge.

Talking Wheelchair



The disabled young man pictured is unable to speak, but he is communicating by means of an electronic system which produces highly intelligible synthesized speech. Known familiarly as the "talking wheelchair" and formally as the Versatile Portable Speech Prosthesis (VPSP), the system incorporates technology developed by Ames Research Center for advanced aircraft communications. The VPSP was developed by Stanford University Medical Center, Stanford, California and Psycho-Linguistic Research Associates, Menlo Park, California with NASA-Ames funding assistance. Other participants include personnel of Ames Research Center, the NASA Biomedical Application Team at Stanford, and Children's Hospital at Stanford.

The wheelchair-mounted system consists of a word processor, a video screen, a voice synthesizer and a computer program which instructs the synthesizer how to produce intelligible sounds in response to user commands. To save time, the computer's memory contains 925 words plus a number of common phrases and questions from which users can construct messages; the memory can also store several thousand other words of the user's choice. Any word not already in the memory can be entered, one letter at a time, and the VPSP will pronounce it. Depending on the user's disability, message units are selected by operating a simple switch, a joystick or a keyboard. The completed message appears on the video screen; then the user activates the speech synthesizer, which generates a voice with a somewhat mechanical tone. Continuing research aims at development of a more natural tone. With the keyboard, an experienced user can construct messages as rapidly as 30 words per minute.

The NASA technology used in the VPSP was developed as an aid to pilots who experience critical aircraft malfunctions. To free the pilot from the necessity for watching several instruments during the emergency, Ames Research Center developed experimental systems to provide synthesized voice readout of aircraft altitude, airspeed, descent rate and deviation from flight path. VPSP co-developer Dr. Carol Simpson, formerly a NASA researcher and now with Psycho-Linguistic Research Associates, applied this technology to the talking wheelchair.

The VPSP offers potential for people—some 1,500,000 in the United States alone—who have lost speech function as a result of such afflictions as stroke, cerebral palsy, muscular dystrophy, Parkinson's disease or multiple sclerosis. A company—Computers for the Physically Handicapped, Huntington Beach, California—has expressed interest in commercial production of the VPSP system and negotiations are under way.

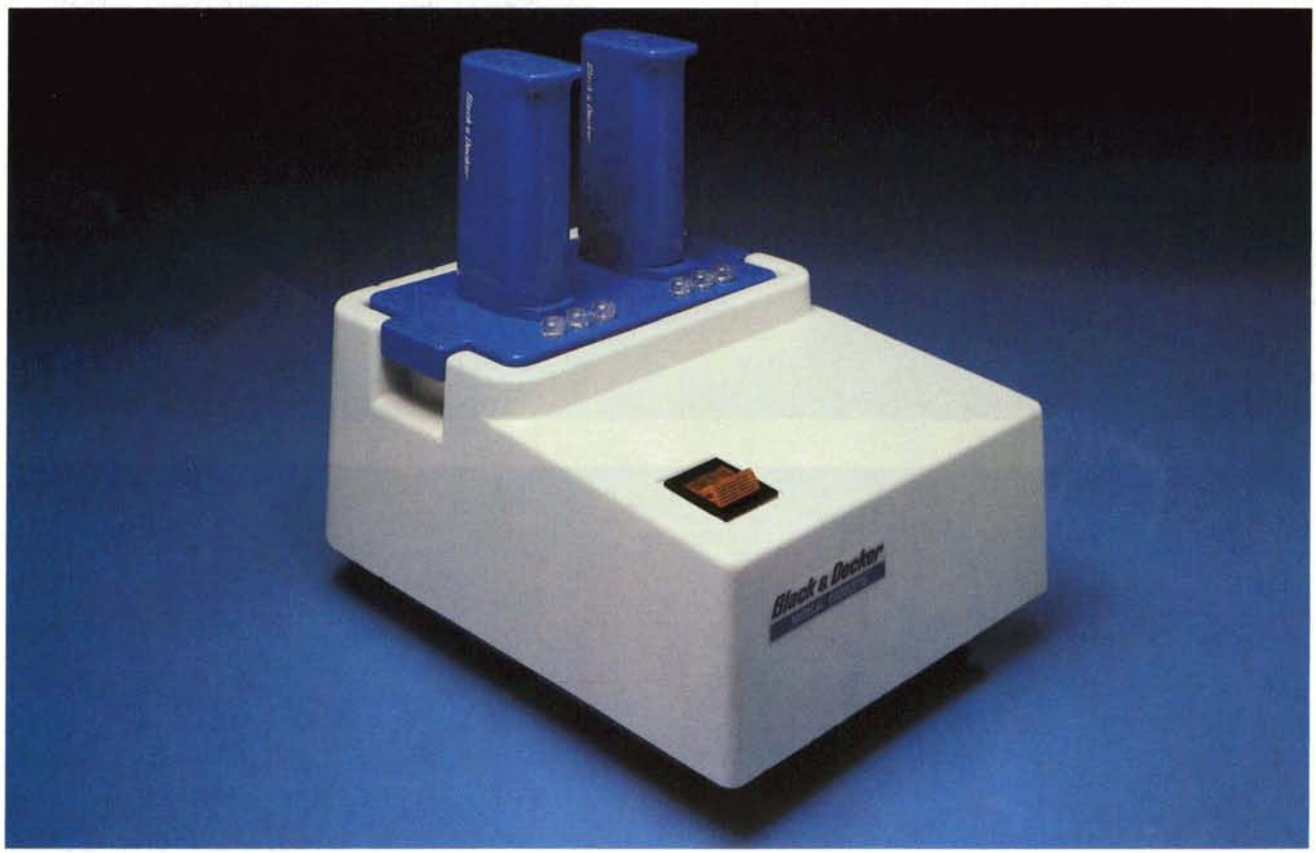
Cordless Instruments

In the photo above, the surgeon is using a completely self-contained powered instrument that needs no connection to a power source. It thus offers advantages over customarily-used surgical instruments powered by compressed gas. Such instruments, which require tanks with connecting lines or hoses, present problems: the tanks must be refilled, the lines and hoses must be sterilized, and the lines can burst or tangle. The cordless unit pictured is one of a new line of lightweight, battery-powered precision instruments designed to give the surgeon optimum freedom and versatility in the operating room. Manufactured by Black & Decker Medical Products, Towson, Maryland, the instruments evolved from the company's participation in the Apollo lunar landing program.

The Black & Decker orthopedic instrument line includes a drill for boring through bone (right), a driver/reamer used for heavy-duty bone shaping, and a sagittal saw for cutting bone without damaging

tissue (left). All provide up to 20 minutes of powered operation—more than enough for most orthopedic procedures—on a single charge. The power pack is the instrument's handle, which can be removed for recharging. A companion microprocessor-controlled recharging unit (bottom) can recharge two power packs simultaneously in 30 minutes. The instruments can be gas-sterilized, steam-sterilized in an autoclave, or immersed for easy cleaning.

The surgical instruments are the latest Black & Decker cordless products rooted in technology acquired by the company in the course of developing a self-contained lunar drill (see page 74). The drill, successfully employed in extracting core samples from beneath the moon's surface, had to be lightweight, compact and independently powered. The motor and battery expertise thus gained, along with a specially-developed computer program used to design the drill's motor, provided a technology base for further Black & Decker development of battery-powered implements.



Compound Separation

Liquid-liquid extraction is a term used in chemical laboratory work to describe a method of separating various chemical compounds contained within biological liquids, such as blood or urine samples. Used for such purposes as medical treatment, pharmaceutical preparation, and forensic chemistry, extraction is a process whereby the compounds to be separated are transferred to a solvent liquid in a series of complicated, time-consuming steps requiring a variety of special equipment.

Looking for a simpler, easier way to separate compounds, Jet Propulsion Laboratory (JPL) developed a new one-step liquid-liquid extraction technique which sharply cuts processing time, reduces costs, and eliminates much of the equipment requirement. The technique employs disposable "extraction columns," or tubes, partially filled with an inert, water-absorbent granular matrix. Shown in the accompanying photos, these columns are now produced commercially by Analytichem International, Inc., Harbor City, California under the trade name Extube®.

In a typical extraction, a liquid sample is poured into an Extube where the filling material absorbs water and

impurities from the sample and spreads the specimen as a very thin film over a large area. To extract a particular compound, an appropriate liquid solvent is introduced to the tube. As the solvent passes through the filling material, the desired compound becomes dissolved in the solvent and exits through the tube's nozzle. A different compound may be extracted from the remaining sample by introducing another solvent. The upper photo on the opposite page shows extraction solvent being delivered from a dispenser to a type of Extube known as Tox Elut®, used for detection of drugs in a sample. At bottom left is another member of the Extube family called Clin Elut®, more highly purified than Tox Elut and employed in more sensitive analytical procedures. Below is a group of larger Chem Tube® columns, used for large volume applications in industrial and environmental analysis.

JPL's original development was undertaken as an aid to the Los Angeles Police Department, allowing more rapid detection of drugs in biological samples as part of the department's drug abuse program. NASA waived title to the invention to the California Institute of Technology (Caltech), JPL's parent organization, and Analytichem International is producing Extubes under Caltech license.

® Extube, Tox Elut, Clin Elut and Chem Tube are registered trademarks of Analytichem International, Inc.

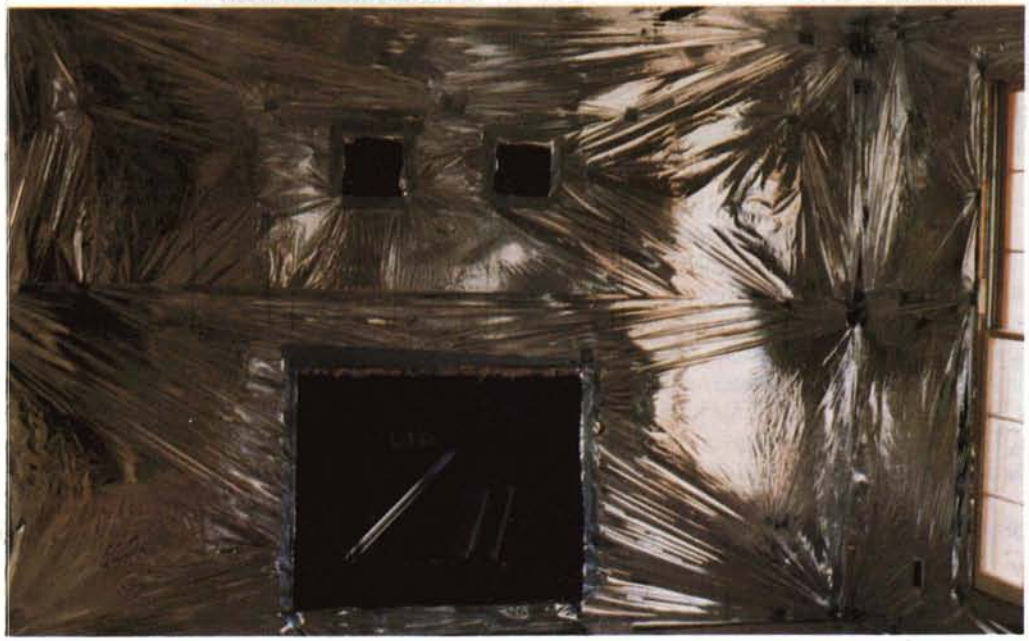
The Watt Count System

A sophisticated approach to home energy efficiency highlights technology transfers in energy supply and conservation

This contemporary home is a "Watt Count house," meaning that it is exceptionally energy-efficient because its design incorporates an energy conservation approach developed by a group of aerospace engineers and known as the Watt Count System.

On a lunar mission, temperatures outside the Apollo spacecraft ranged from a searing 400 degrees Fahrenheit to a supercold minus 400 degrees. Yet, inside Apollo, astronauts worked in something approximating homelike conditions, thanks to a highly advanced environmental control system whose total energy expenditure was equivalent to that of ten 150-watt electric light bulbs.

Apollo's extraordinary energy efficiency impressed even the people who helped develop the spacecraft and sparked an idea: why not apply similar methodology to Earth structures? From that idea, there has emerged a superefficient energy conservation technique known as the Watt Count System, which combines aerospace and computer technology,



Among spinoff features of the Watt Count System is use of aluminized "heat shield" insulation once employed as a radiation barrier in the Apollo spacecraft.

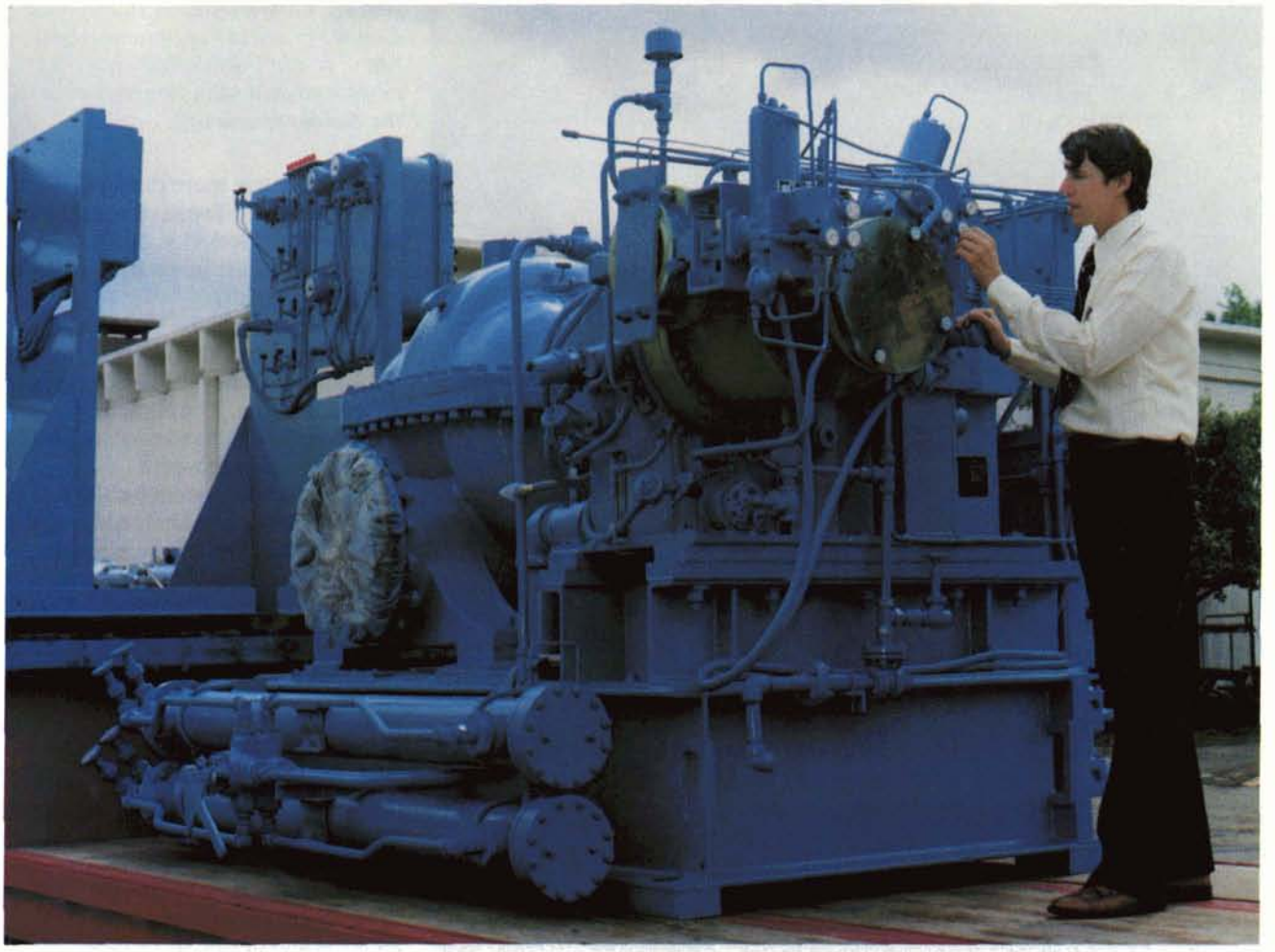
an engineering systems design approach, and the environmental control expertise of a group of engineers who worked on Apollo.

Watt Count originated at Arnold Engineering Development Center, Tullahoma, Tennessee, which was engaged in test and evaluation of Apollo systems. Among the center's personnel were four engineers involved in energy transfer research who recognized that some of the space technology could effectively be applied to reduce energy consumption in residential and commercial buildings. The first Watt Count homes, built during the early 1970s, showed impressive results. After refining and improving their techniques, the group incorporated in 1977 as Watt Count Engineering Systems, Nashville, Tennessee.

Today there are more than 600 Watt Count homes in Tennessee, others in neighboring Kentucky, and acceptance of the innovative system is growing rapidly.

The first step in the Watt Count System is a computerized energy consumption analysis based on plans for a new home. The company calculates heating and cooling loads and customizes the most energy-efficient system for the particular structure analyzed. Optimum insulation is combined with a specifically-designed heat pump central heating and air conditioning system. Installation of insulation and heating/cooling equipment is handled by a network of authorized dealers whose personnel are specially trained in Watt Count methodology. During construction, Watt Count provides a quality control engineer to assure that insulation and ducting are installed according to specifications. Watt Count officials say their analysis and design techniques are so accurate they are able to give homeowners a two-year guarantee that the home's energy consumption will not exceed the kilowatt hour level determined by the computer in the energy consumption analysis.

A key factor in the Watt Count System is careful selection of insulating materials, several types of which may be used in a single structure. A distinguishing Watt Count feature is the use—usually on walls exposed to the outside—of a highly effective aluminized "heat shield" once employed as a radiation barrier on the Apollo Command and Lunar Modules and on other space systems; this material serves to hold in or keep out radiant heat, air flow and water vapor. The combination of Watt Count techniques provides sharp reductions in energy costs, company officials say; they cite an annual energy performance comparison in which a Watt Count home used 45 percent less energy than a conventionally-equipped equivalent home next door.



Steam Turbines

The photo shows a radial inflow steam turbine and water pump ready for shipment to a Gulf Coast refinery for application to a cooling tower circulating water system. It is representative of a line of high-efficiency, energy-conserving turbines produced by Turbonetics Energy, Inc., a subsidiary of Mechanical Technology, Inc., (MTI) Latham, New York. Turbonetics' steam turbines are used as power generating systems in the oil and gas, chemical, pharmaceutical, metals and mining, and pulp and paper industries.

Development of the Turbonetics line benefited from use of NASA research data on radial inflow steam turbines and from company contact with personnel of Lewis Research Center. The company's product engineering group also uses Lewis-developed computer programs to determine performance characteristics of the turbines.

Another MTI group—the Research and Development Division—is making use of NASA technology in work for the Office of Naval Research on an Axial Compressor Test Development Project. This project aims at expanding the technology of using helium as a motive fluid for high-efficiency turbomachinery. In designing a helium compressor test system for study of compressor blade efficiency and other performance characteristics, the division applied the Lewis-developed Computer Programs for Axial Flow Compressor Design. MTI reports substantial time and money savings through use of the programs, which were made available by NASA's Computer Software Management and Information Center (COSMIC)® at the University of Georgia.

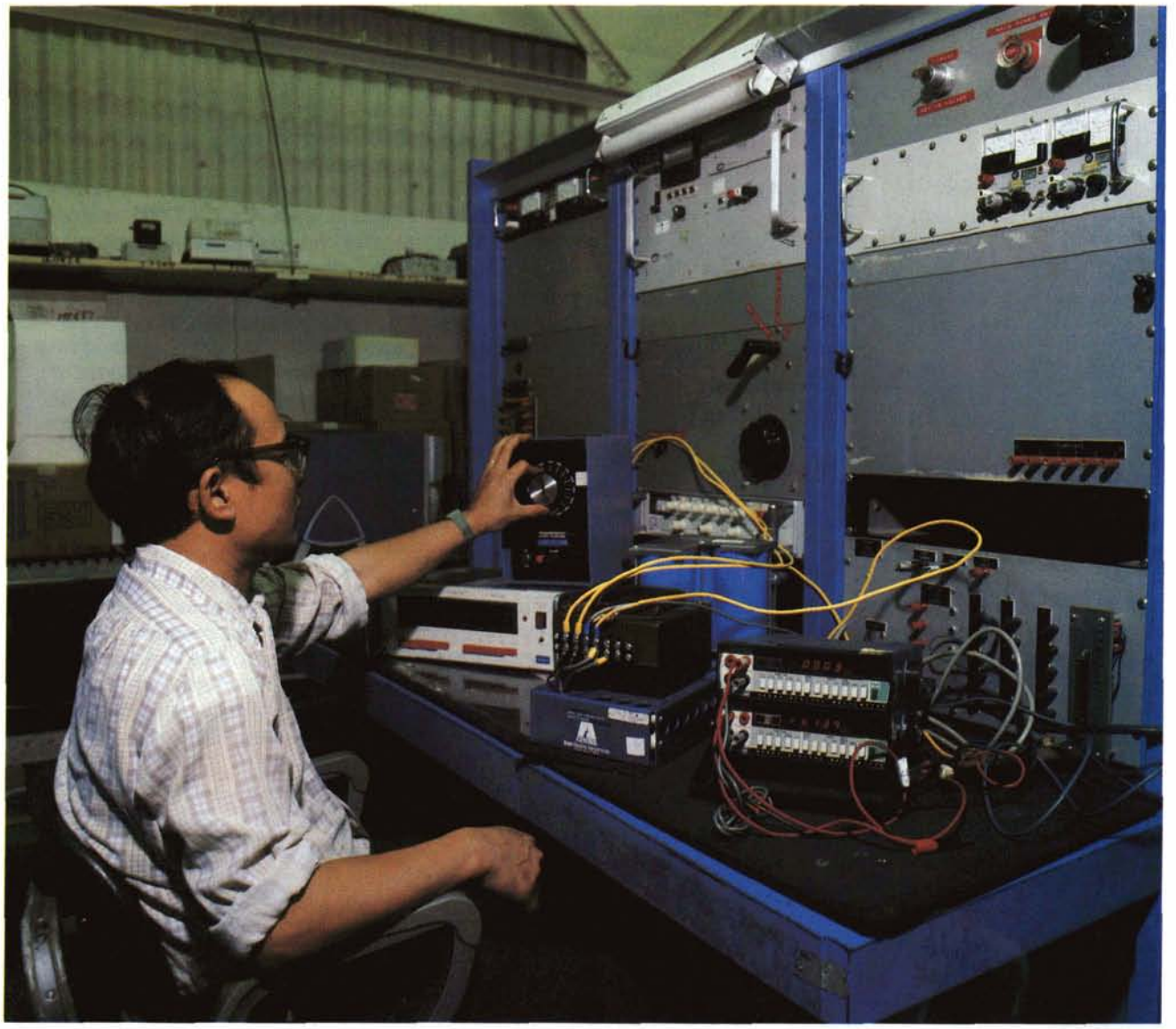
®COSMIC is a registered trademark of the National Aeronautics and Space Administration.

Switching Transistor

Under contract with Lewis Research Center, Westinghouse Electric Corporation's Research and Development Center, Pittsburgh, Pennsylvania developed a new class of power switching transistors for improved electrical power distribution systems in aircraft and spacecraft; they are used, for example, in the actuators that move flight control surfaces on the Space Shuttle. The D60T transistor, which represents a major advance in the field of power electronics, is being produced for the commercial market by the company's Semiconductor Division, Youngwood, Pennsylvania.

D60T transistors are used primarily as switching devices for controlling high power in electrical circuits. With expanded power ranges, low energy losses and exceptionally fast switching speeds, the D60T enables reduction in the number and size of circuit components and promotes more efficient use of energy. It opens the door to previously impractical transistor applications, says Westinghouse; in many uses, the new transistor will compete directly with the thyristor, long the workhorse of the electrical power industry. It combines thyristor advantages of high power handling and reliability with the transistor's faster switching speed, positive circuit control and convenience of manufacture.

Westinghouse is using the transistors in its own product line and supplying them to other electronic systems manufacturers for a wide range of applications, from a popcorn popper to a radio frequency generator for solar cell production. The accompanying photos illustrate two other application examples. At left is a battery charger for electric vehicles, produced by EHV Systems, Centerreach, New York. The tugboat shown below has a National Controls inverter which changes DC power to AC for operation of such equipment aboard the tug as refrigerators and air conditioners.



Quality Assurance

General Electric Company's Nuclear Energy Division, San Jose, California produces nuclear reactors for electric power utilities. One aspect of the design and manufacturing process, illustrated in the accompanying photo, is quality assurance testing of the various components used in reactor instrumentation. In this work, the division's engineers and technicians are aided by NASA-developed reliability data on electronic and electromechanical components.

To meet the demanding requirements of spacecraft design and fabrication, Jet Propulsion Laboratory (JPL) developed a set of techniques for evaluating the reliability of components used throughout the electronics industry. The results of this work were presented in a comprehensive technical report covering 10 general categories of electronic and electromechanical components. For each category, the report provides detailed information on failure modes, stress analysis, and other reliability considerations.

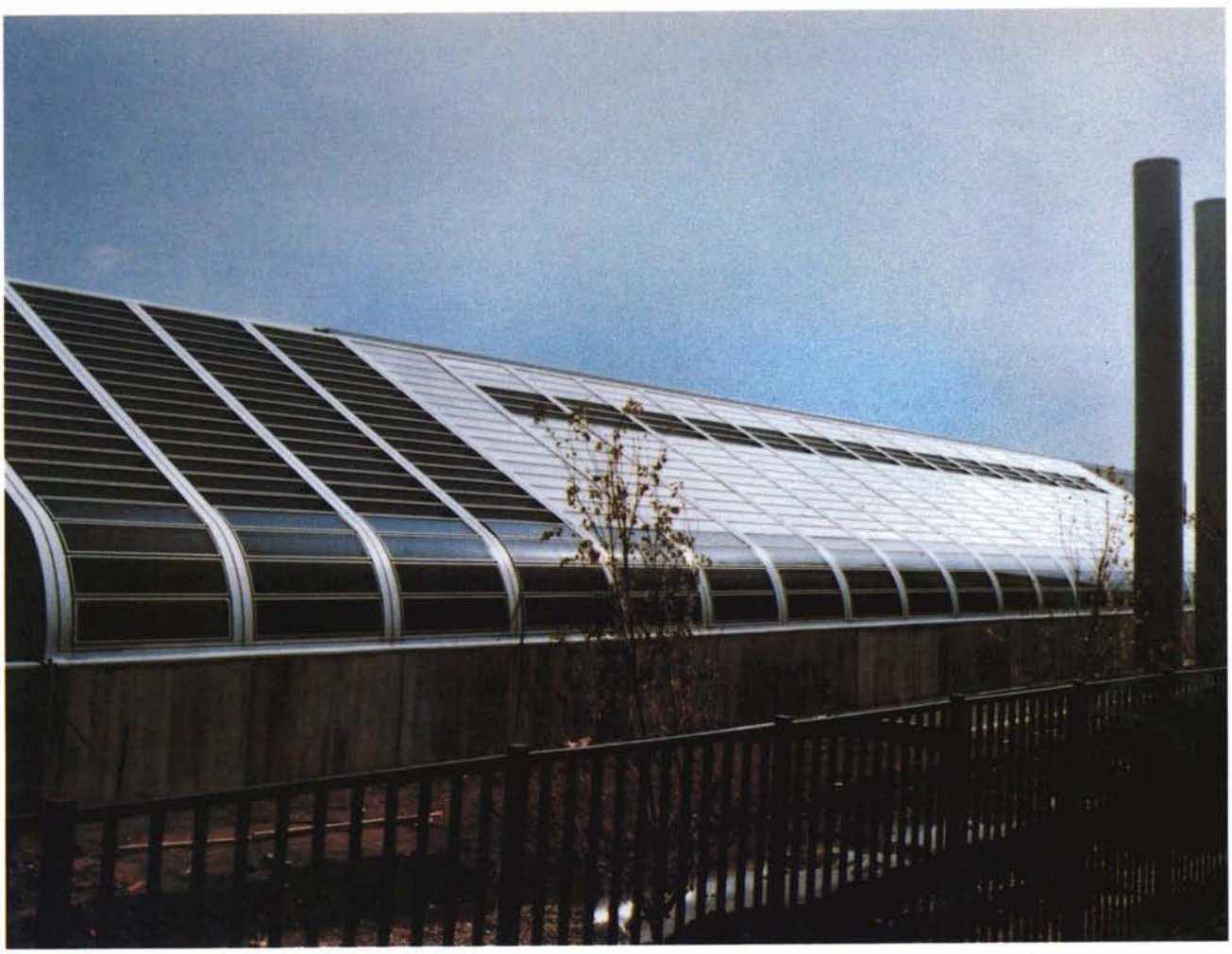
A Nuclear Energy Division engineer learned of the JPL report through *Tech Briefs*, NASA's quarterly publication which announces new technology developed by NASA or by contractors in the course of work for NASA. The engineer requested the report and incorporated its information in the division's quality assurance procedures. Routinely used, the report enables personnel time savings in establishing applicable screening test data that would otherwise require independent research.

Solar Energy Systems

The structure in the upper photo is a wastewater treatment plant in Wilton, Maine, where sewage sludge is converted to methane gas. The array of solar collectors which forms the roof of the building plays an important part in the chemical conversion of waste to energy; it supplies heat for the bacteria which "digest" the sludge and generate gas in the process. In the lower photo is Monsanto Company's Environmental Health Laboratory in St. Louis, Missouri, where more than 200 solar collectors provide preheating of boiler feed water for laboratory use; solar energy furnishes about 30 percent of the facility's hot water requirements.

The collectors shown are representative of the Grumman Sunstream line of solar energy equipment, produced by Grumman Energy Systems, Inc., Bohemia, New York. The firm is a subsidiary of the company which built the Apollo Lunar Module that enabled NASA astronauts to descend to the surface of the moon. Technology derived from the Lunar Module program benefited development of the Grumman Sunstream line. Under contract to Johnson Space Center, Grumman Aerospace Corporation, Bethpage, New York, conducted "thermal modeling" studies to determine the effects of heat on a wide variety of spacecraft

components. The project included formulation of computer programs to simulate and display the reactions of various materials and structures to thermal stress. Grumman Aerospace prepared a handbook detailing procedures for modeling the effects of heat loads and describing the associated computer programs. This technology was later applied to development of Grumman's thermal analyzer system for testing solar collectors to insure maximum efficiency. Grumman Energy Systems reported that use of NASA-developed thermal modeling techniques contributed to the design of its collectors and saved years of engineering test time.



Solar Heating Equipment

Located in Cookeville, Tennessee, the home pictured uses energy collected by the solar array at right for heating water and part of the house. This solar system is designed for the homeowner who wants more than water heating but whose roof space or budget rules out a whole-house heating system; it is intended for heating the one area of the home used most frequently, for example, a den/kitchen combination. The array pictured is one element of the Suncatcher® solar equipment line—produced by Solar Unlimited Incorporated, Huntsville, Alabama—whose development was aided by NASA design management techniques.

The Suncatcher line includes a variety of solar arrays for water heating only, for partial home heating or for water and whole-house central heating. The company also manufactures associated heat exchangers, pumps, storage tanks, controls and other equipment.

The techniques employed in designing Solar Unlimited products represent an example of the personnel-type spinoff, wherein an aerospace scientist, engineer or management executive moves to a new field of endeavor and applies his aerospace know-how to development of non-aerospace products. Solar Unlimited's founder and president Donald R. Bowden was a NASA employee for 20 years and was manager of the solar heating and cooling program conducted for the Department of Energy by Marshall Space Flight Center. Bowden credits adoption of NASA's systematic development process as a major contributing factor in public acceptance of Suncatcher products. Employed in managing design and development of complex aerospace programs, the process involves earliest consideration of potential performance problems and establishment of performance criteria before moving into the design or materials procurement phases. Using this approach, Solar Unlimited developed a set of rigorous requirements to avoid problems common to solar heating technologies. An example cited by the company is use of silicone fluids as the medium for transferring solar heat to the water in storage tanks; silicone was used to avoid potential problems of fluid freezing (which can burst pipes), boiling (which requires fluid replacement) and corrosive reaction (which may cause system deterioration).

®Suncatcher is a registered trademark of Solar Unlimited Incorporated.

Solar Simulator

In the photo, a technician is examining a plant specimen to study its sunlight absorption. The "sunlight" is provided by a solar simulator, one of several produced by Oriel Corporation, Stamford, Connecticut. The simulators are laboratory tools for such purposes as testing and calibrating solar cells or other solar energy systems; testing dyes, paints and pigments, pharmaceuticals and cosmetic preparations; plant and animal studies, food and agriculture studies and oceanographic research.

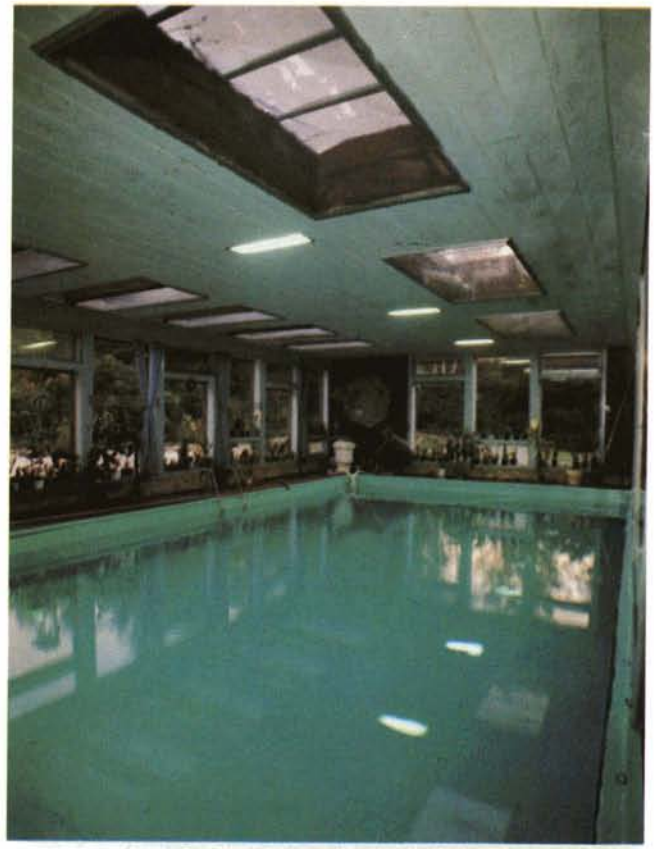
Heart of the Oriel simulators is a high pressure xenon lamp whose reflected light is processed by an optical system to produce a uniform solar beam. Because of the many different applications, the simulators must be adjustable to replicate many different areas of the solar radiation spectrum. For example, the systems can closely simulate solar radiation as it occurs in airless space, or simulate terrestrial solar radiation which is different because Earth's atmosphere absorbs and scatters the Sun's rays.

In developing simulators capable of reproducing close approximations of these and other solar spectral characteristics, Oriel Corporation drew upon NASA technology developed by Goddard Space Flight Center. Seeking solar radiation information important to establishing design criteria for space vehicles, Goddard scientists compiled extensive data—from ground-based, aircraft and sounding rocket tests—on the spectral distribution and total irradiance of the Sun. Oriel Corporation learned of this technology through NASA's New England Research Applications Center, made follow-up contact with Goddard scientists, and used the NASA measurements to model solar simulations.

Homemade Solar Systems

Like other Americans, Peter Kask is concerned about the cost and possible shortage of energy—and he is doing something about it with the help of NASA technical information. A civil engineer who lives in Huntington, New York, Kask plans eventual independence of fossil fuel energy by substituting solar energy systems for all home needs. As a first step, he has "solarized" his home's domestic hot water supply and his heated swimming pool (right).

In NASA's *Tech Briefs,* a quarterly technical information journal, Kask read of a design for a low-cost solar collector system. Applying the design information, he was able to build the swimming pool heating system with minimal outlay for materials. Shown below left, the system consists of two long collectors utilizing inexpensive aluminum plates to absorb the sun's heat. Mounted on the pool's roof, the collectors are built into water troughs constructed of plywood, insulated with styrofoam and made leakproof by a layer of polyethylene film. Heat absorbed by the collectors is transferred directly to the water, which is ducted into the pool. Another *Tech Briefs* report supplied information which helped Kask build the domestic hot water system pictured below right. The two solar panels, bought commercially, are mounted on a structure which can be moved in two axes to track the sun as it changes position, thus increasing the efficiency of the collectors.

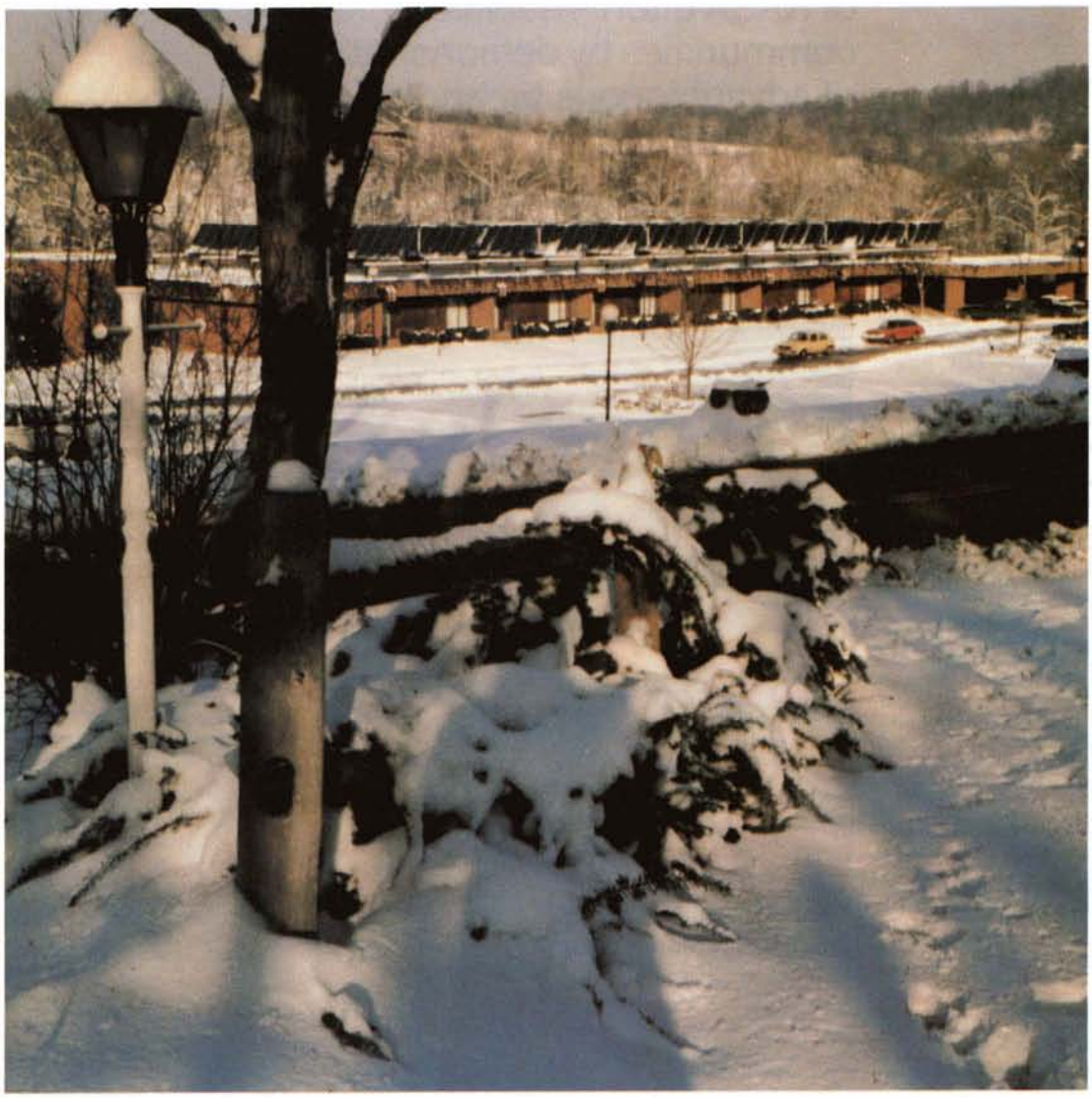


Solar System Controller

The building pictured is part of Bethany College, an 800-student liberal arts institution located in Bethany, West Virginia. The college has a solar heating and cooling system whose control design is based largely on NASA technology. Designed by Apollo Energy Control, Inc., Gainesville, Virginia, the system includes 5,000 square feet of flat plate solar collectors and an 7,500 gallon water storage tank; it supplies 78 percent of the college's domestic hot water, 68 percent of its space heating and 80 percent of the air conditioning.

The control design evolved from a computerized programmable controller developed at Marshall Space Flight Center for measuring differential temperatures in solar heating systems and for turning on and off pumps and backup systems. The pumps, fans and control valves are operated by a series of relay outputs.

The president of Apollo Energy Control learned of the controller through a magazine article and requested detailed technical information from Marshall. He attributes about 90 percent of the Bethany College control design to the information provided. It helped the company design a highly reliable, simply operated system and allowed substantial savings in engineering time. Apollo Energy Control is now using the information as part of a training course for mechanics.



Profit from a Problem

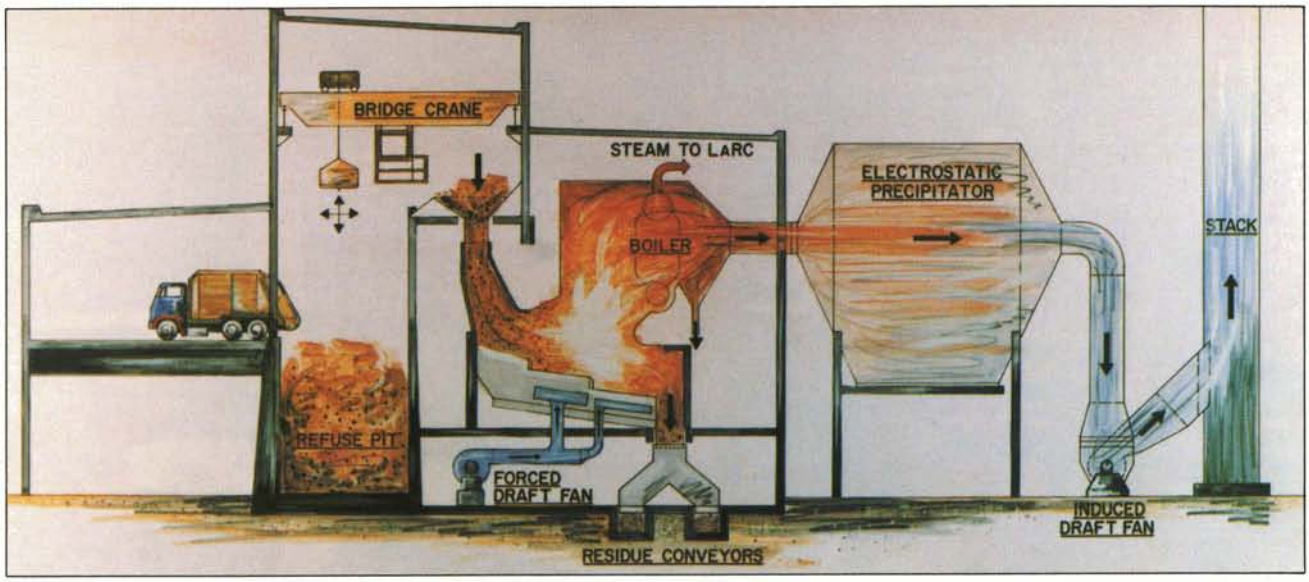
A trash-fueled energy production facility exemplifies a special area of NASA effort—service to communities by demonstrations of advantageous technology

Late last year, a new facility at Langley Research Center began operational service. It is not a facility for advanced space research, nor a wind tunnel for probing the frontiers of atmospheric flight. It is simply a trash-burning steam plant—but, like Langley's more exotic work, it represents a pioneering effort. It provides a design base for modeling similar projects elsewhere, to the benefit of national energy conservation, and it also solves a local environmental problem.

The problem—shared by a growing number of communities—was how to dispose of refuse in a Virginia coastal area where acceptable landfill sites are scarce. The solution—the Refuse-fired Steam Generating Facility—not only meets disposal needs, it offers a bonus by using trash instead of oil as fuel for energy production.

Before the facility went into service, Langley Research Center and adjacent Langley Air Force Base

At Langley Research Center, the facility shown at top burns refuse to generate steam. At right, solid waste is crane-lifted into an incinerating system. The next steps are shown in the diagram on the opposite page; the electrostatic precipitator cleans combustion gases before they are expelled through the stack.



used a landfill on government property. But the low elevation of the land and the possibility of subsurface water contamination made it extremely difficult to meet Environmental Protection Agency regulations, and there was no other suitable land for disposal operations. The nearby city of Hampton faced similar problems; its own landfill, daily receiving solid waste from a population of 140,000, was expected to be filled by the early 1990s.

Jointly sponsored by Hampton, NASA-Langley and Langley Air Force Base, the Refuse-fired Steam Generating Facility disposes of all solid waste from the NASA center, the Air Force base, the Army's Fort Monroe and other federal installations in the area; it also accommodates about 70 percent of Hampton's municipal waste. The incinerated refuse is reduced to a readily-disposable ash whose volume is only one-seventh that of the solid waste brought to the plant. The energy produced in the burning process is converted to steam for use in research and administrative facilities at Langley Research Center. The system offers these advantages:

- The need for federal landfill operations is eliminated.
- Waste dumped in the city's landfill is reduced by about 70 percent, extending the landfill's useful life to 33-40 years.
- The amount of fuel oil normally used by Langley Research Center to generate steam for its facilities is cut by more than two million gallons a year.
- Combined costs of refuse disposal and steam production are lower.

Langley Research Center supervised design and construction of the facility, assisted by prime contractor J. M. Kenith Company, Atlanta, Georgia and the architectural engineering firm Wiley and Wilson, Lynchburg, Virginia. Through a bond issue, the City of Hampton financed approximately 70 percent of the cost; NASA-Langley and Langley Air Force Base provided the remainder.

Built on government land, the plant remains NASA's property, but Hampton will operate it for at least 20 years under a lease arrangement. The city will realize revenue from refuse disposal fees paid by all of the organizations involved and from sale of steam to NASA-Langley. The revenue will cover the facility's operating expenses and additionally allow payoff of the city bonds over the 20-year period.

The process of producing steam from refuse is relatively simple. Trucks haul in about 200 tons of solid waste daily and dump it in a refuse pit. The waste is then crane-lifted, dropped through a chute into a dual furnace/boiler system and incinerated. The resulting ash drops out of the boilers onto conveyors, is picked up by trucks and transported to the Hampton landfill. The gases created by the burning process are cleaned by a precipitator system before they are expelled into the atmosphere.

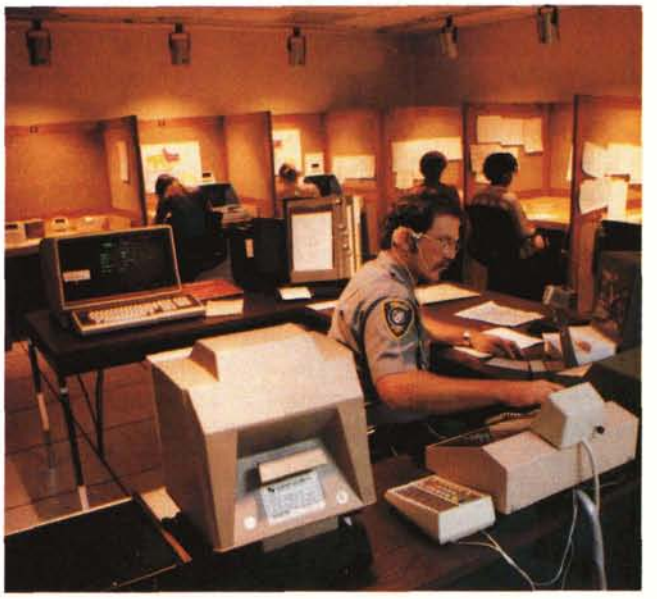
The high-intensity heat—about 1800 degrees Fahrenheit—generated by burning waste is used to convert water flowing through the walls of the twin boilers into steam. The plant is expected to produce some 300 million pounds of steam annually, about 85 percent of Langley Research Center's needs.

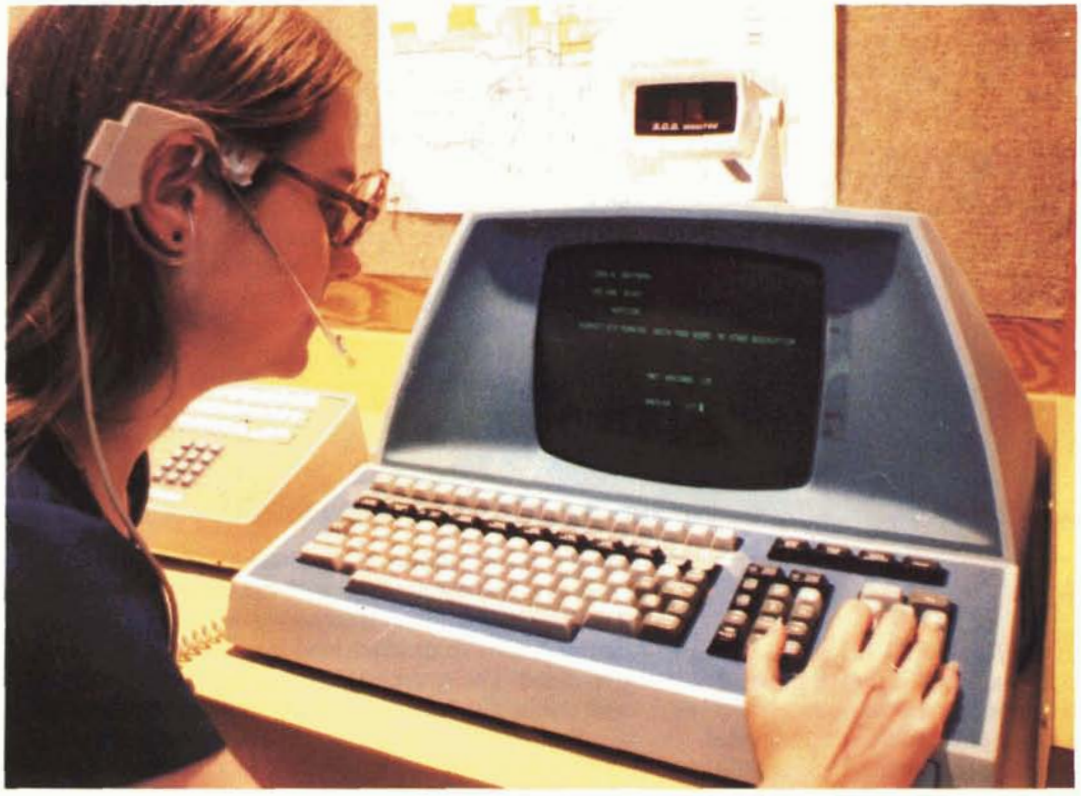
This project is an example of NASA's community service effort, in which the agency provides technological assistance—to communities, state and local governments, medical institutions and other organizations—with the aim of broadening technology awareness. In this instance, the technology was largely "off-the-shelf" and NASA's contribution consisted of technical and management expertise. In other cases, NASA demonstrates use of advanced technology to solve major problems or to provide better ways of meeting public needs. In this special area of technology transfer, some product spinoff may evolve from the technology applied, but product commercialization is not the primary aim; the intent is to pave the way for community-sponsored application of beneficial technology.

Police Communications

Shown in the accompanying photos is the communications center of the Oklahoma City Police Department (OCPD), whose display consoles bear some resemblance to those in the mission control facility at Johnson Space Center (JSC). The resemblance is more than coincidental. OCPD incorporated NASA technology in its computer-aided communications system and benefited from assistance provided by JSC.

JSC's Mission Control is a vital element in space operations and its efficient operation is as important to mission success as the spacecraft in orbit. Developed in 1960, Mission Control was provided entirely new, specially-designed communications, computing and

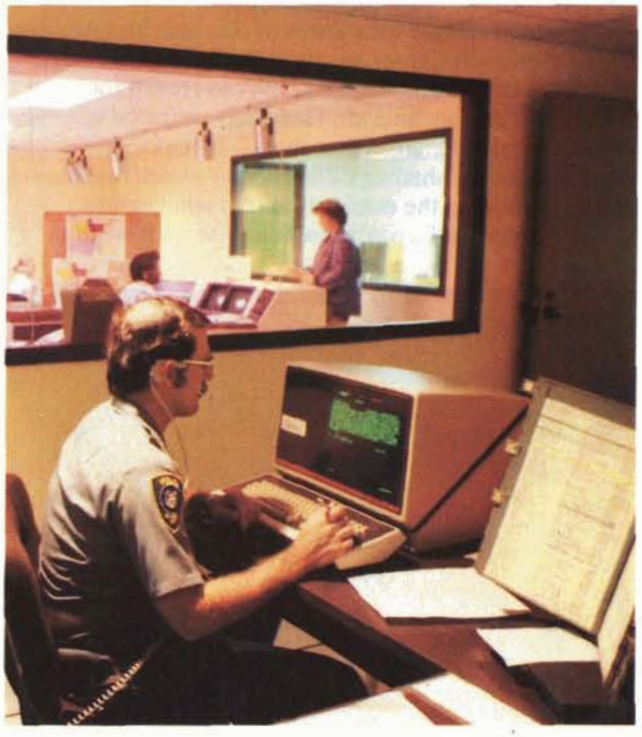




display systems which have been technologically updated over the years. In designing the facility, NASA paid particular attention to the human factors involved in ground management of long-duration space flights, for example, selection and training of control center personnel; most effective informational displays; and special lighting to reduce controller fatigue and eyestrain. For the benefit of potential users of this technology, NASA has conducted a number of seminars and workshops on control equipment and techniques.

When the Oklahoma City Police Department decided to develop a computerized communications system, OCPD sought assistance from Johnson Space Center. JSC officials reviewed the Oklahoma City plan, furnished information on lighting and other fatigue-reducing measures, and provided specifications for equipment and design layouts. JSC was particularly helpful in advising how to avoid communications bottlenecks associated with simultaneous handling of telephone, radio and inter-office transmissions. Use of already-developed NASA technology also saved Oklahoma City money in reduced design and engineering costs.

The photos show some of the main features of OCPD's highly efficient communications system. At upper left, the police officer in foreground, seated at a computer display console, is the dispatch coordinator; in the background are three other dispatchers at identical consoles. The officer (opposite) is the telecommunications coordinator, who handles internal calls from OCPD offices. Public calls for assistance are received by telephone clerks (above). Radio messages—incoming calls and dispatch transmissions—are handled separately by a radio communications coordinator (right).

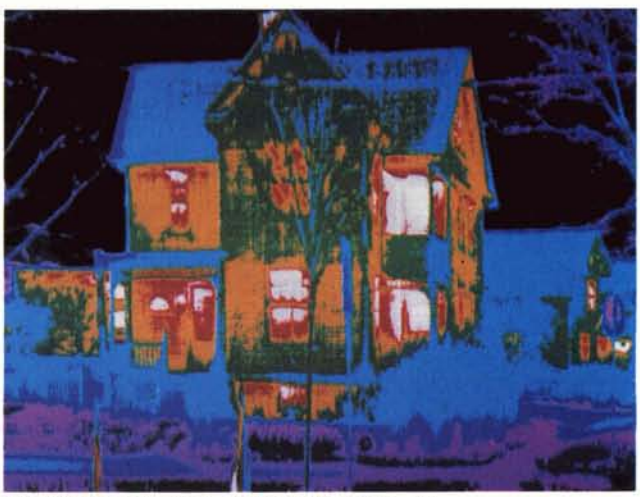


Texas Instruments Incorporated and Iowa Utility Association

Heat Loss Imagery

Since the oil embargo of 1973, NASA has been increasingly active in the national energy program, not only in technology development for new energy sources but also in promoting more efficient use of traditional fossil fuels. It is estimated that almost 30 percent of the fuel burned for heating residences and larger buildings escapes through inadequately insulated walls and roofs. To help focus public awareness of this heat loss problem, Lewis Research Center has used the remote sensing technique of infrared thermography to record roof temperatures from aircraft. Generally, infrared scanning devices produce images that show—by color or black-and-white shading differences—which buildings are losing heat to the outdoors and to what extent.

An example of Lewis' community service work in energy conservation is an "outreach" project—undertaken in cooperation with the City of Cleveland and the East Ohio Gas Company—wherein Lewis used aerial thermography to produce heat loss images of sections of Cleveland. The cooperating agencies then followed up with public displays, neighborhood meetings and wide distribution of informational packages. The program, which has met with considerable success, was aimed at educating the public to the mechanisms of heat loss and motivating homeowners to install more effective insulation. As a by-product, it stimulated interest in thermographic services provided by commercial firms, examples of which are shown above and left.



VANSCAN Thermogram, Daedalus Enterprises, Inc.

Texas Instruments Incorporated, Dallas, Texas manufactures the RS-300 series scanners and conducts airborne heat loss surveys, such as Operation Sky Scan, in which some 900 communities in Iowa, South Dakota and Illinois were surveyed. The upper illustration is an example of the black-and-white imagery produced in Sky Scan. The shades of gray represent the amount of thermal energy radiating from the residential area pictured; houses with the lightest roof tones are losing the most heat. Large-area surveys like Sky Scan provide a method of evaluating heat loss in residential, commercial and industrial areas at relatively low single-building cost.

Daedalus Enterprises, Inc., Ann Arbor, Michigan produces several types of airborne infrared and multispectral scanners. The company has developed a patented ground-mobile technique to use this technology for scanning building sidewalls for heat loss. At left is a VANSCAN® thermograph showing varying degrees of heat loss through walls and windows of a residential building; white, red and yellow indicate greatest heat loss, blue and blue-green show losses of lesser degree. Texas Instruments, Daedalus and other companies conducting heat loss surveys are experiencing growing acceptance of their services among industrial firms, utilities, local governments, state and federal agencies interested in promoting heat loss awareness and inspiring corrective actions.

®VANSCAN is a registered trademark of Daedalus Enterprises, Inc.

Protective Face Mask

The boy pictured is a cerebral palsy victim who is undergoing training at the Southeastern Training Center, Portsmouth, Virginia. His physical impairment causes frequent falls while walking, which in the past often resulted in head and facial injuries. In response to a request for a device to prevent such injuries, Langley Research Center fabricated the protective mask shown.

The mask is made of composite materials being developed at Langley for aerospace applications. Composites—usually graphite or boron fibers woven into a matrix—are generally lighter but stronger than the metals they are intended to replace, hence the mask provides the requisite protection although it weighs less than three ounces. The boy has worn the mask for more than a year without incidence of injury. Southeastern Training Center has expressed gratitude for the durability and trainee acceptance of the device.

Solar Air Sampler

Installed at Liberty State Park, New Jersey, adjacent to the Statue of Liberty, the system shown is the nation's first solar cell-powered air monitoring station. It is one of more than 100 air sampling facilities operated by the New Jersey Department of Environmental Protection to determine whether air quality meets state and federal standards. Jointly sponsored by state agencies and the Department of Energy, the system includes a display which describes its operation to park visitors, a means of promoting public interest in photovoltaic (solar cell) technology.

The unit samples air every sixth day for a period of 24 hours. Air is forced through a glass fiber filter which traps minute particulate matter. The filter is removed each week for examination by the New Jersey Bureau of Air Pollution.

Heart of the quietly-operating, non-polluting monitoring station is the solar cell array, composed of 860 silicon cells which convert sunlight to 360 watts of electric power. During the day, the solar cells provide total power for the sampling equipment. Excess energy is stored in a bank of lead-acid batteries. The station draws electricity from the batteries during nighttime and the early morning hours of the weekly sampling cycle. The monitoring system was produced under management of Lewis Research Center as part of the Department of Energy's National Photovoltaic Conversion Program.

Technology Transfer

A description of the mechanisms employed by NASA to encourage and facilitate new applications of aerospace technology in the interests of national productivity

Putting Technology to Work

In a comprehensive nationwide effort, NASA seeks to increase public and private sector benefits by broadening and accelerating the transfer of aerospace technology

180

At Duke University Medical School, members of the Research Triangle Institute Biomedical Application Team examine a "radiological phantom," a model which simulates a person or a specimen to be x-rayed. The model is used in research designed to improve the efficacy of computerized "CAT-scan" systems, which x-ray specimens from multiple directions to allow more comprehensive scrutiny. Problem-solving application teams represent one of a number of mechanisms employed to promote technology transfer.

The wealth of aerospace technology generated by NASA programs is an important resource, a foundation for development of new products and processes with resultant contribution to expanded national productivity. In a dormant state, however, the technology has only potential benefit. One of NASA's jobs is to translate that potential into reality by putting the technology to work in new applications. The instrument of this objective is the Technology Transfer Program.

The program's aim is to increase the return on the national aerospace investment by identifying new ways to employ aerospace technology and by making the technology more readily available to prospective users. The effort embraces two major areas: (1) facilitating broader application of remote sensing technology and (2) fostering technology utilization, or encouraging re-use of technology emerging from NASA's mainline research programs.

Satellite remote sensing is a means of acquiring voluminous information about Earth's surface. When combined with information from conventional sources, satellite data offers vast potential for more effective management of Earth's resources. The Technology Transfer Program seeks to bring about wider use of remote sensing technology by generating greater awareness of the benefit potential and by providing assistance to organizations interested in developing their own capabilities in this promising field.

In the technology utilization element of the program, NASA promotes secondary application of aerospace technology by disseminating information on the technology available for transfer, by assisting industry in the transfer process, and by adapting existing aerospace technology to the solution of public sector problems.

Focal point of the program is the Technology Transfer Division, a component of NASA's Office of Space and Terrestrial Applications headquartered in Washington, D.C. The division coordinates the activities of a nationwide network of technologists who provide a link between the developers of aerospace technology and those who might effectively employ it, either in remote sensing operations or in non-aerospace reapplications. The mechanisms employed to meet program objectives include:

- Liaison and awareness activities with regard to remote sensing applications, whereby NASA establishes relationships and maintains two-way communications with the user community.
- The Applications Systems Verification and Transfer (ASVT) program, which involves representative demonstrations of remote sensing technology to verify processes, techniques and institutional approaches for the use of satellite data in specific applications.
- The Regional Remote Sensing Applications Program, designed to promote transfer of proven, low-risk remote sensing applications—already verified by ASVTs and other research and development programs—to a broader user community.
- The University Applications Program, an instrument for building university remote sensing capabilities, thereby creating additional sources of expertise for conducting research, training personnel and stimulating interest among state and local users.
- Applications engineering projects, wherein NASA, in cooperation with the private sector, undertakes adaptation of existing technology to specified needs of government agencies and public sector groups.
- Application teams, groups of technologists representing multiple disciplines, who provide problem-solving assistance to public sector organizations and private industry.
- A network of dissemination centers, channels through which industrial firms and other organizations interested in secondary utilization of technology may avail themselves of NASA scientific, technical and management expertise.

181

NASA's Computer Software Management and Information Center at the University of Georgia stores more than 1,500 computer programs and makes them available to industrial firms and government agencies for re-use.

- Publications and announcement media, designed to acquaint potential users with available technologies emanating from aerospace research and development.
- A specialized center which provides aerospace-developed and other government-generated computer programs adaptable to the needs of industry and government agencies.

Remote Sensing Activities

Satellite remote sensing offers extraordinary benefit potential in a great many areas—for example, agricultural inventories; land, water and forest resources management; monitoring urban growth patterns; mapping; flood impact study; and a variety of environmental/ecological applications. It is being used for these and other purposes by a growing number of private sector and government organizations, the latter including federal, state, regional and local agencies.

The Technology Transfer Program seeks to expand the potential benefits of remote sensing by establishing liaison with current and prospective users to generate greater awareness of the technology. Awareness is promoted through university programs, symposia, workshops, publications and direct contact with personnel of organizations which could employ remotely-sensed data to advantage.

A major mechanism is the Applications Systems Verification and Transfer project, or ASVT. Conducted in cooperation with a representative user organization, the ASVT is a validation of technology created in two earlier steps in the transfer cycle: NASA research and development of concepts for specific applications, and Applications Pilot Tests which apply these concepts. ASVTs are undertaken when there is evidence of real user need, where the demonstration may inspire operational use of the technology, and where the potential benefits justify the demonstration. The emphasis in projects of this type is on adaptive engineering—refining the technology to make it compatible with the user's equipment and institutional environment, and working to reduce the cost to the user of operational employment of the technology.

NASA maintains continuing two-way communications with active users, keeping user organizations informed of new capabilities. Users, in turn, advise NASA of results and difficulties in employing satellite data; this "feedback" serves to guide NASA program planning.

Remotely-sensed information is particularly valuable to state policy makers and management officials, who have special need for comprehensive, up-to-date information on which to base management and planning decisions involving natural and man-made resources. Nearly all of the 50 states have used remote sensing to some degree; a number of them have set up their own operational systems for extracting and employing information derived from satellite data. Technology Transfer Program personnel maintain direct contact with state officials and also make use of other national channels as an aid to identifying user needs, disseminating information, and acquiring feedback. These channels are the National Conference of State Legislatures, the National Governors Association, and the National Association of Counties.

182

Regional Program

To encourage the transfer of remote sensing technology and facilitate broader operational use, NASA maintains a Regional Remote Sensing Applications Program. User assistance is organized on a geographical basis, with activities concentrated in three of NASA's field centers.

Ames Research Center, Moffett Field, California deals with user organizations in 14 western states, including Alaska and Hawaii. NASA's National Space Technology Laboratories, NSTL Station, Mississippi serves 17 states in the midwest, south and southeast. Goddard Space Flight Center, Greenbelt, Maryland is responsible for user liaison in 19 eastern/northeastern states plus Puerto Rico and the Virgin Islands. Each of the regional centers has the full range of equipment and know-how needed to assist both new and experienced users in making use of remotely-acquired data and information extraction techniques. When necessary, they draw upon the resources and expertise of the other NASA centers.

The regional centers provide training, conduct small scale demonstration projects, and offer technical assistance to on-going users. An initial training phase involves basic orientation to acquaint decision makers and other personnel with remote sensing capabilities. Facilities such as the computer-equipped mobile van shown at left make it possible to bring this introduction to remote sensing to the user's doorstep.

In a more advanced course, technicians of user organizations get "hands-on" training and experience in data analysis techniques as a prelude to participation in demonstration projects. Demonstrations selected are based on well-proven, low-risk applications suitable for operational use in resource management programs.

Organizations which elect to develop capabilities for using satellite data sometimes face problems in assessing their hardware and software requirements and in successfully applying the data to specific needs. Therefore, NASA provides continuing assistance to users, to help them become self-sufficient in applying remote sensing technology and to draw upon existing university and private sector sources for further training, analysis services, hardware, software and other types of technical assistance.

Regional activities principally have focused on state government applications, but NASA has also addressed the somewhat different needs of sub-state governments—such as counties—and encouraged greater private sector involvement in supporting users of the technology. As user capabilities for applying remotely-sensed data become more widely established, the technology transfer process is the key to adaptation and introduction of new technology to operational use.

University Program

Employed primarily as an instrument for building university capabilities in remote sensing, the University Applications Program is complementary to, but somewhat different from, such other user development activities as ASVTs or regional programs. Through grants to universities, NASA has developed new sources of remote sensing expertise within the states, with the goal of facilitating independent state or local government use of the technology. NASA funds about 20 university programs a year and spreads the programs geographically, with the ultimate aim of creating university capabilities in all the states.

The university applications group is composed of faculty members and graduate students representing a number of different scientific/technological disciplines. It has a threefold assignment: to stimulate interest among prospective users of satellite-derived information; to conduct the research and development necessary to adapt remote sensing technology to solution of a specific problem; and to demonstrate the applicability of the technology. The groups search—within their states and usually at the sub-state level—for urgent problems which seem capable of solution by application of remote sensing techniques. Applications selected for demonstration are those which have not previously been tested and which, if successful, may inspire further use of the technology demonstrated. Projects are conducted on a one-time-only basis under NASA grant funding, but a successful application often results in follow-on projects of a similar nature, carried out with state funding or supported by user fees. Grants are retired on a time-phased basis and a number of universities have "graduated" from the program and have become self-sustaining sources of remote-sensing expertise.

Technology Applications

One facet of NASA's Technology Transfer Program is its applications engineering effort, which involves the use of NASA expertise to redesign and reengineer existing aerospace technology for the solution of problems encountered by federal agencies, other public sector institutions or industry.

Applications engineering projects originate in one of three ways. Some stem from requests for NASA assistance from other government agencies; others are generated by NASA technologists or application teams who perceive possible solutions to public sector problems by adapting NASA technology to the need. NASA employs six application teams, each team composed of several scientists and engineers representing different areas of expertise. These teams contact public sector agencies, medical institutions, trade and professional organizations to uncover significant problems which might be susceptible to solution by application of NASA technology. Located at research institutes and universities, the application teams concentrate their efforts in the fields of health care, public safety, transportation and industrial productivity.

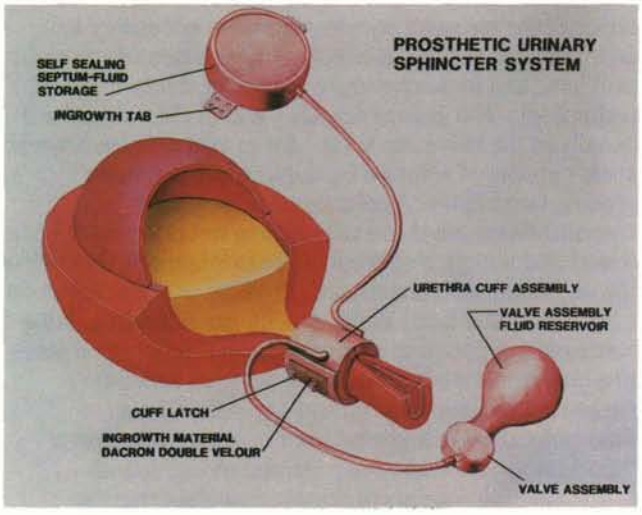
An example of an applications engineering project is a prosthetic urinary sphincter being developed by Marshall Space Flight Center in cooperation with Rochester General Hospital (RGH), Rochester, New York. The NASA Biomedical Application Team at Research Triangle Institute, Research Triangle Park, North Carolina is coordinating activities among Marshall, RGH and two participating medical equipment manufacturers. The human-implantable prosthesis is intended to help the many people who suffer from severe urinary incontinence, which drastically affects the sufferer's ability to lead a normal existence.

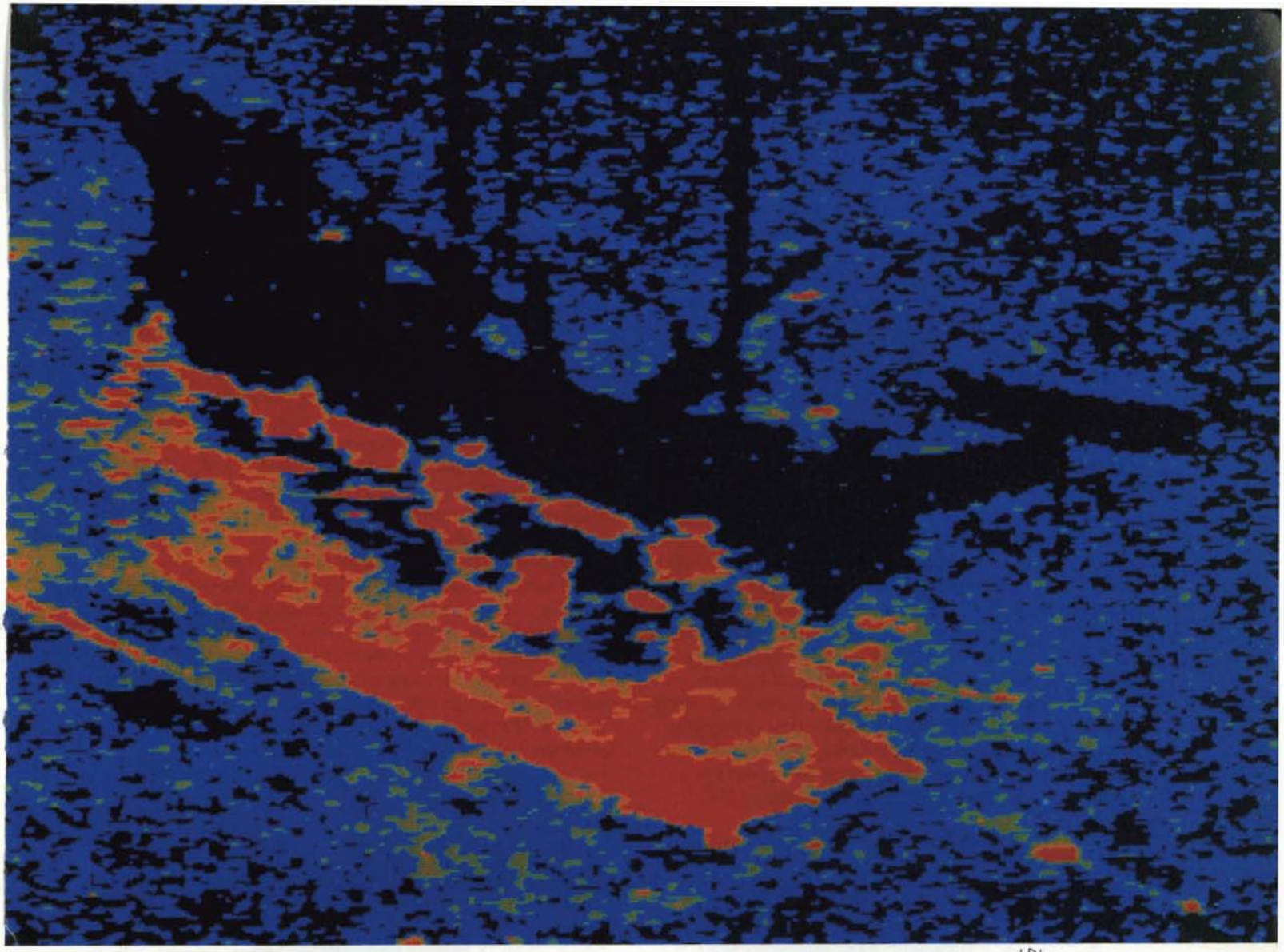
A malfunctioning sphincter is often responsible for the inability to control emptying of the bladder. Continence can sometimes be restored by an implanted device that occludes (closes) the urethra, the canal which carries off the urine in the bladder; the device allows voluntary voiding by manual release of the occluding pressure. However, two factors have prevented widespread acceptance of existing devices by the medical community: the surgical complexity of the implantation procedure and a high rate of device malfunction, often due to valve failure.

The NASA/RGH project is an effort to obviate such objections through development of a simpler, more reliable system for occluding the urethra. Key to the development is adaptation of the low pressure, zero leakage, high reliability valves used on the Viking spacecraft. The two manufacturers—Parker-Hannifin Corporation, Irvine, California and Medical Engineering Corporation, Racine, Wisconsin—are jointly fabricating a valve/bulb assembly designed for commercial application after successful completion of clinical trials.

The illustration below left shows the operation of the prosthetic urinary sphincter system, which is implanted so that the valve/bulb assembly is accessible to manual pressure through the skin. The cuff applies pressure to occlude the urethra and maintain continence. The pressure can be released for voiding, then restored, by manual manipulation of the valve. Animal implants have performed within design limits and the results of animal tests indicate reduced surgical complexity and operating time for human implantations. Plans call for the start of clinical trials late in 1981.

Another technology application example is a wearable speech "autocuer" based on integrated circuit, microprocessor, quality assurance and automatic checkout technology developed for spacecraft use by Goddard Space Flight Center (GSFC). The autocuer is a lip-reading aid designed to enhance the ability of deaf and hearing-impaired persons, of whom there are more than 13 million in the United States, to function in a normal environment. Used in conjunction with lip reading, cueing by finger signals greatly increases the intelligibility of speech to the hearing-impaired because it eliminates ambiguities or multiple sounds associated with similar lip shapes. The drawback is that the speaking person must possess the ability to cue speech manually, a requirement that could be eliminated by the automatic cueing device. The autocuer is being developed by GSFC; Gallaudet College, Washington, D.C.; and the Research Triangle





Institute. Telesensory Systems, Inc., Palo Alto, California will produce field test units of the device.

The autocuer system is shown at left. It consists of two principal segments: a battery-powered, miniaturized electronic system, roughly the size of a cigarette pack, and an eyeglass display unit. Subassemblies within the electronic system extract speech parameters and analyze them to derive cues for accurate speech perception by the hearing-impaired user. A microcomputer converts the cues to display symbols, which are relayed to circuitry within the templepiece of the eyeglasses; the cues appear in red on the specially-designed lenses. Field tests of the autocuer are planned for 1982.

A third example is Jet Propulsion Laboratory's work in applying space-developed computer image processing technology to more accurate seafloor surveying. The need for learning more about what the seafloor looks like stems from increased interest in undersea energy and mineral deposits, and by a requirement for study of hazardous areas of the continental shelf and slope regions—areas such as those subject to slides, debris flows or tectonic/seismic activity.

Seafloor imaging can be accomplished by processing data from side-looking sonars, but geological interpretation of these images has been hampered by inherent geometric distortion. The problem can be countered by JPL-developed techniques of image geometry restoration and enhancement. JPL has demonstrated these techniques in computer processing of sonar images provided by the United Kingdom's Institute of Oceanographic Sciences, the U.S. Geological Survey, and the Canada Center for Inland Waters (CCIW).

The illustration above is a digitally-processed sonar image of the American schooner *Hamilton*, one of two ships which sank in Lake Ontario during the War of 1812 and which now rest on the lake bed, largely intact, under 300 feet of water. The image is a false-color rendition of side-looking sonar signals acquired by CCIW and provided to JPL for computer processing. JPL digitized the signals and corrected them for shading variations. The image was then further processed to correct for geometric distortion occasioned by the speed of the sonar-carrying ship and by the angle and distance from the sonar to the *Hamilton*. Processing of low-intensity signals produced the black outline of the *Hamilton*, clearly showing hull, masts and bowsprit. The red outline of the ship and the green areas indicating other artifacts resulted from processing moderate and high-intensity signals. This enhancement technique offers important potential for expanding the interpretative capability of the undersea geologist and for development of large area seafloor resource maps.

Dissemination Centers

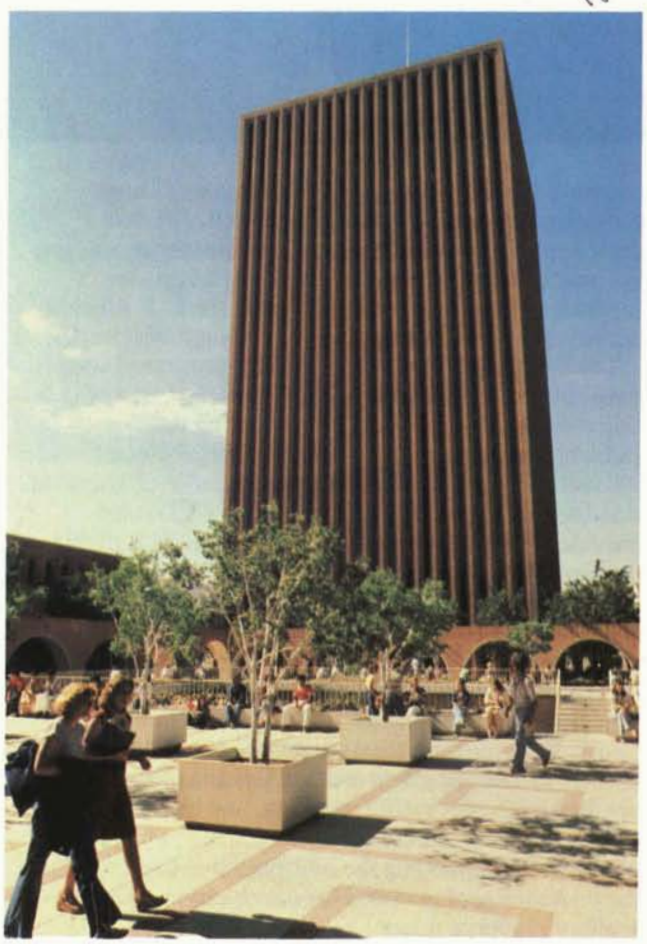
To promote technology transfer, NASA operates a network of dissemination centers whose job is to provide information retrieval services and technical assistance to industrial and government clients. The network consists of seven Industrial Applications Centers (IAC) and two State Technology Applications Centers (STAC) affiliated with universities across the country, each serving a geographical area. The centers are backed by off-site representatives in many major cities and by technology coordinators at NASA field centers; the latter seek to match NASA expertise and ongoing research and engineering with client problems and interests.

The network's principal resource is a vast storehouse of accumulated technical knowledge, computerized for ready retrieval. Through the applications centers, clients have access to some 10 million documents, one of the world's largest repositories of technical data. Almost two million of these documents are contained in the NASA data bank, which includes reports covering every field of aerospace-related activity plus the continually updated contents of 15,000 scientific and technical journals.

Intended to prevent wasteful duplication of research already accomplished, the IACs endeavor to broaden and expedite technology transfer by helping industry to find and apply information pertinent to a company's projects or problems. By taking advantage of IAC services, businesses can save time and money and the nation benefits through increased industrial efficiency and productivity.

Staffed by scientists, engineers and computer retrieval specialists, the IACs provide three basic types of services. To an industrial firm contemplating a new research and development program or seeking to solve a problem, they offer "retrospective searches"; they probe appropriate data banks for relevant literature and provide abstracts or full-text reports on subjects applicable to the company's needs. IACs also provide "current awareness" services, tailored periodic reports designed to keep a company's executives or engineers abreast of the latest developments in their fields with a minimal investment of time. Additionally, IAC engineers offer highly skilled assistance in applying the information retrieved to the company's best advantage. The IACs charge a nominal fee for their services.

The State Technology Applications Centers supplement the IAC system. They facilitate technology transfer to state and local governments, as well as to private industry, by working with existing state mechanisms which provide technical assistance. The STACs perform services similar to those of the IACs, but where the IAC operates on a regional basis, the STAC works within an individual state. In effect, the STAC program focuses on areas not normally served by the IACs, especially in the less industrialized states and among small businesses.



Publications

An essential step in promoting greater use of NASA technology is letting potential users know what NASA-developed information and technologies are available for transfer. This is accomplished by means of several types of publications.

The National Aeronautics and Space Act requires NASA contractors to furnish written reports containing technical information about inventions, improvements or innovations developed in the course of work for NASA. These reports provide input to NASA's principal technology utilization publication, *Tech Briefs*. Issued quarterly, *Tech Briefs* provides current awareness or problem-solving tools for its more than 70,000 industrial subscribers. Each issue contains information on approximately 140 newly-developed processes, advances in basic and applied research, improvements in shop and laboratory techniques, new sources of technical data and computer programs.

#26

Interested firms can follow up by requesting a Technical Support Package, which provides more detailed information on a particular product or process described in the publication. Innovations reported in *Tech Briefs* last year generated more than 200,000 requests for additional information, concrete evidence that the publication is playing an important part in inspiring broader secondary use of NASA technology.

Subscription to *Tech Briefs* is free to engineers in U.S. industry, business executives, state and local government officials and other qualified technology transfer agents. The publication may be obtained by contacting the Director, Technology Transfer Division, NASA Scientific and Technical Information Facility, Post Office Box 8757, Baltimore/Washington. International Airport, Maryland 21240.

NASA also publishes the announcement bulletin *Computer Program Abstracts* and a variety of special publications. The latter are reports, technical handbooks and data compilations designed to acquaint the non-aerospace user with NASA advances in various states of the art. Most of these publications are available through the National Technical Information Service, Springfield, Virginia 22161. A list of titles and prices is available from the Director, Technology Transfer Division, at the address listed earlier.

Software Center

Like hardware technology, computer programs have secondary applicability; programs developed for one purpose can often be adapted to another. To help industrial firms, government agencies and other organizations take advantage of this type of technology transfer, NASA operates the Computer Software Management and Information Center (COSMIC),® located at the University of Georgia. COSMIC collects, screens and stores computer programs developed by NASA and other technology-generating agencies of the government. The center's library contains more than 1,500 programs, which perform such tasks as structural analysis, electronic circuit design, chemical analysis, design of fluid systems, determination of building energy requirements and a variety of other functions. COSMIC offers these programs at a fraction of their original cost and the service has found wide acceptance. Availability of potentially adaptable programs is announced in the NASA publication *Computer Program Abstracts*, which may be obtained through the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. For additional information on COSMIC's services, contact the director at the address listed in the directory which follows.

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NASA's Technology Transfer Network

The NASA system of technology transfer personnel and facilities extends from coast to coast and provides geographical coverage of the nation's primary industrial concentrations, together with regional coverage of state and local governments engaged in transfer activities.

★ *Field Center Technology Utilization Officers:* manage center participation in regional technology utilization activities.

✪ *Regional Remote Sensing Applications Centers:* provide training, conduct demonstrations and offer technical assistance to users of remote sensing data.

● *Industrial Applications Centers:* provide information retrieval services and assistance in applying relevant technical information to user needs.

□ *State Technology Applications Centers:* provide technology transfer services similar to those of the Industrial Applications Centers, but only to state governments and small business within the state.

○ *The Computer Software Management and Information Center (COSMIC):* offers government-developed computer programs adaptable to secondary use.

▲ *Application Teams:* work with public agencies in applying aerospace technology to solution of public sector problems.

For specific information concerning the activities described above, contact the appropriate technology transfer personnel at the addresses listed on the following pages. For information of a general nature about the Technology Transfer Program, address inquiries to the Director, Technology Transfer Division, NASA Scientific and Technical Information Facility, Post Office Box 8757, Baltimore/Washington International Airport, Maryland 21240.

Field Centers

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, California 94035

Technology Utilization Officer: *Stan Miller*
Phone: (415) 965-6471

Hugh L. Dryden Flight Research Center
National Aeronautics and Space Administration
Post Office Box 273
Edwards, California 93523

Technology Utilization Office: *Gussie Anderson (acting)*
Phone: (805) 258-3311, Ext. 787

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland 20771

Technology Utilization Officer: *Donald S. Friedman*
Phone: (301) 344-6242

Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, Texas 77058

Technology Utilization Officer: *John T. Wheeler*
Phone: (713) 483-3809

John F. Kennedy Space Center
National Aeronautics and Space Administration
Kennedy Space Center, Florida 32899

Technology Utilization Officer: *U. Reed Barnett*
Phone: (305) 867-3017

Langley Research Center
National Aeronautics and Space Administration
Langley Station
Hampton, Virginia 23655

Technology Utilization and
Applications Programs Officer: *John Samos*
Phone: (804) 827-3281

Lewis Research Center
National Aeronautics and Space Administration
21000 Brookpark Road
Cleveland, Ohio 44135

Technology Utilization Officer: *Harrison Allen, Jr.*
Phone: (216) 433-4000, Ext. 422

George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812

Director, Technology Utilization Office:
Ismael Akbay
Phone: (205) 453-2223

Wallops Flight Center
National Aeronautics and Space Administration
Wallops Island, Virginia 23337

Technology Utilization Officer: *Gilmore H. Trafford*
Phone: (804) 824-3411, Ext. 201

Resident Office
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, California 91103

Technology Utilization Officer: *Aubrey D. Smith*
Phone: (213) 354-4849

Regional Remote Sensing Applications Centers

Ames Research Center
Moffett Field, California 94035

Chief, Technology Applications Branch:
Dale Lumb, Ph.D.
Phone: (415) 965-5900

Goddard Space Flight Center
Greenbelt, Maryland 20771

Head, Eastern Regional
Remote Sensing Applications Center: *Philip Cressy, Ph.D.*
Phone: (301) 344-7658

National Space Technology Laboratories
Earth Resources Laboratory
NSTL Station
Mississippi, 39529

Manager, Earth Resources Laboratory: *Wayne Mooneyhan*
Phone: (601) 688-2042

NASA Headquarters
Technology Transfer Division
Office of Space and Terrestrial Applications
Washington, D.C. 20546

Manager, Regional Remote
Sensing Aplications Program: *Richard H. Weinstein*
Phone: (202) 755-7450

Industrial Applications Centers

Aerospace Research Applications Center
1201 East 38th Street
Indianapolis, Indiana 46205

John Ulrich, director
Phone: (317) 264-4644

Kerr Industrial Applications Center
Southeastern Oklahoma State University
Durant, Oklahoma 74701

James S. Harmon, Ph.D., director
Phone: (405) 924-6822

NASA Industrial Applications Center
701 LIS Building
University of Pittsburgh
Pittsburgh, Pennsylvania 15260

Paul A. McWilliams, Ph.D., executive director
Phone: (412) 624-5211

NASA Industrial Applications Center
University of Southern California
Denney Research Building
University Park
Los Angeles, California 90007

Robert Mixer, Ph.D., director
Phone: (213) 743-6132

New England Research Applications Center
Mansfield Professional Park
Storrs, Connecticut 06268

Daniel Wilde, Ph.D., director
Phone: (203) 486-4533

North Carolina Science and
Technology Research Center
Post Office Box 12235
Research Triangle Park, North Carolina 27709

James E. Vann, Ph.D., director
Phone: (919) 549-0671

Technology Applications Center
University of New Mexico
2500 Central Avenue, S.E.
Albuquerque, New Mexico 87131

Stanley Morain, Ph.D., director
Phone: (505) 277-3622

State Technology Applications Centers

NASA/Florida State Technology Applications Center
State University System of Florida
500 Weil Hall
Gainesville, Florida 32611

J. Ronald Thornton, director
Phone: (904) 392-6626

NASA/UK Technology Applications Program
University of Kentucky
109 Kinkead Hall
Lexington, Kentucky 40506

William R. Strong, manager
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Computer Software Management and Information Center

COSMIC
112 Barrow Hall
University of Georgia
Athens, Georgia 30602

Robert L. Brugh, Ph.D., director
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Biomedical Application Teams

Advisory Center for Medical Technology & Systems
University of Wisconsin
1500 Johnson Drive
Madison, Wisconsin 53706

William N. Fetzner, Ph.D., director
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Research Triangle Institute
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Research Triangle Park, North Carolina 27709

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Stanford University School of Medicine
Cardiology Division
Biomedical Technology Transfer
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Palo Alto, California 94303

Gary Steinman, Ph.D., assistant director
Phone: (415) 497-5353

Technology Application Teams

IIT Research Institute
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Chicago, Illinois 60616

Edmund R. Bangs, director
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SRI International
333 Ravenswood Avenue
Menlo Park, California 94026

James P. Wilhelm, director
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Technology + Economics, Inc.
2225 Massachusetts Avenue
Cambridge, Massachusetts 02140

David J. MacFayden, director
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National Aeronautics and
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